JOURNAL OF THE AMERICAN WELDING SOCIETY

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Help!

For the first time in the history of the American Welding Society it may be necessary to report a decrease in the number of members of the Society at the Annual Meeting. You can prevent this by cooperation and assistance.

The finances of the Society are not such as to permit an active membership campaign at this time as it would involve postage, circular letters and printing bills. However, if every member would bring the work of the Society to the attention of a friend who should be a member, the same result would be accomplished. Leaflets describing in brief form the activities of the Society and advantages of becoming affiliated with it may be obtained at headquarters. A simple form of membership application is given on the back of the leaflet.

During the coming year there will be published a number of important technical committee reports, codes and standards. The research department of the Society continues to be active. The national and local meetings are a source of profitable information to everyone interested in welding. The dues for Associate Members are $10.00 per year which is a small amount for any prospective member to pay in comparison with the returns to be derived from affiliation with the Society.

The growth of the Society and the industry is important to every member. We should not permit a membership report at the end of the year which will show a net loss of membership.

A. E. GAYNOR, *Chairman, Membership Committee*

A Message

Reprinted from January 2, 1932, issue *Electrical World*.

"My message to you is to be courageous. I have lived a long time. I have seen history repeat itself again and again. I have seen many depressions in business. Always America has come out strong and more prosperous. Be as brave as your fathers were before you. Have faith—go forward."—THOMAS A. EDISON.

A.S.T.M. to Hold Joint Meeting with A.I.M.E. with Cooperation of the A.W.S.

A joint meeting of the American Society for Testing Materials and members of the Iron and Steel Division, Institute of Metals Division and New York Section of the American Institute of Mining and Metallurgical Engineers will be held on the evening of February 18th.

There will be several important papers on metals.

In keeping with the general topic of the evening there will be a demonstration of ten different tests of welds given by A. B. Kinzel and W. B. Miller, Union Carbide and Carbon Research Laboratories, Inc., and John J. Crowe, Air Reduction Laboratories, Inc.

These tests will be as follows:

1. Visual Inspections
2. Hammer and Anvil Nick-Break Test
3. Bending Test
4. Tension Test
5. Hardness Test
6. Specific Gravity Test
7. Stethoscopic Test
8. Invisible Ray Test
9. Compression and Drift Test
10. Hydrostatic Internal Pressure Test

All who are interested in the subject of this meeting are cordially invited to attend. It is scheduled to begin at 8 P.M.

American Road Builders Show

The American Road Builders will hold their Annual Meeting in Detroit, January 11th to 15th. In connection with this meeting there will be the 29th Annual Road Show at the Municipal Airport Building. Several welding exhibitions will be shown and Professor F. P. McKibben, Senior Vice-President of the American Welding Society, will present a paper on Welding as Applied to Highway Bridges.

Lukens Steel Company Founds Industrial Fellowship at Mellon Institute

Dr. Edward R. Weidlein, Director, Mellon Institute of Industrial Research, Pittsburgh, Pa., has announced that the Lukens Steel Company of Coatesville, Pa., has established in the Institute an Industrial Fellowship whose purpose is the scientific investigation of processes employed in the manufacture of steel plates.

Erle G. Hill, who received his professional education at the University of California, has been appointed to the incumbency of this Fellowship. He is a specialist in iron and steel technology who was previously associate professor of metallurgy in the School of Mines of the University of Pittsburgh.

Printing of Journal

Beginning with this issue the JOURNAL is being printed by the Mack Printing Company at Easton, Pennsylvania. This Company also prints a number of other technical periodicals including *Civil Engineering, Mechanical Engineering, Industrial and Engineering Chemistry, Metals and Alloys, Technical Reports of the N.E.L.A.* and many others. Arrangements have been made with this organization so that superior services may be offered in the matter of reprints of articles appearing in the JOURNAL. Authors desiring to have reprints made should notify Society headquarters in advance that these reprints will be wanted. The number of reprints and instructions as to title page should accompany these orders if possible.

In order to meet the requirements of the postoffice the address of the publication office will hereafter appear on the title page of the Journal as Easton, Pa. However, all communications should be addressed as formerly to the office of the Society at 33 West 39th Street, New York.

Resistance Welder Manufacturers Association

A Resistance Welder Manufacturers Association has been recently organized. The officers are: Mr. G. A. Cutter of the Thomson-Gibb Electric Welding Company, Lynn, Mass., Chairman; Mr. R. G. English of the Swift Electric Welder Company, Detroit, Michigan, Secretary-Treasurer.

The object of the Association is to increase the use of Resistance Welding. By cooperation the manufacturers hope to keep the public accurately informed as to its possibilities and to have welding apparatus and welding service of a high standard of quality always available.

The members of this Association are: American Electric Fusion Corp., Chicago, Ill.; Federal Machine & Welder Co., Warren, Ohio; Swift Electric Welder Co., Detroit, Mich.; Taylor-Winfield Corp., Detroit, Mich.; Thomson-Gibb Electric Welding Co., Lynn, Mass., & Bay City, Mich.

Low Pressure Tankage

Elsewhere in this JOURNAL there is printed material on a "Code for the Welded Construction of Low Pressure Tankage." This material was submitted by the Building Code Committee with a request that those who have experience in this field submit papers on the subject for publication in the JOURNAL OF THE AMERICAN WELDING SOCIETY. Members and others interested are requested to cooperate. Articles dealing with design, methods of construction, technique of welding and tests of product are particularly desired.

SECTION ACTIVITIES

BOSTON

The December meeting of the Boston Section was held in the Engineering Societies' Rooms on December 18th. An interesting paper on the new Lindewelder blowpipe was presented by Mr. L. F. Jackson of the Linde Air Products Company who sponsored this meeting. The paper was supplemented by motion pictures showing the use of this equipment in field welding of natural gas pipe lines. The construction and operation of the blowpipe was explained in detail, and after the meeting many inspected the blowpipe which was on exhibition. An interesting discussion followed the presentation of the paper.

CLEVELAND

"Welding as Applied to the Construction of the *Akron*," will be the subject of the January 20, 1932, meeting of the Cleveland Section. The speaker will be Paul Ffield, Metallurgical Engineer, Goodyear Zeppelin Corporation. Mr. Ffield will also exhibit a film of standard 35 mm size showing in detail the construction of the *Akron* from laying of the ring to the take-off for Lakehurst.

On January 14th the Cleveland Section, in collaboration with Fenn College and the Linde Air Products Company, exhibited an interesting motion picture film on the general subject of "Linde-Welding." The film was accompanied by a live demonstration and also by a discussion on some of the most recent developments in the oxy-acetylene industry.

DETROIT

The first meeting of the new season held by the Detroit Section was a joint meeting with the Detroit Engineering Society on December 18th. The speaker was Mr. A. R. Ellis, Vice-President of the Pittsburgh Testing Laboratory, who described an 18-story all-welded building put up without the usual amount of guy wires by using a patented step connection. He also described the stethoscope method of testing the welds and stated that on this building the stethoscope method discovered some bad welding and was responsible for the removal of the welding thus found.

The next meeting of this Section will be held January 21, 1932, at which time Mr. F. P. McBerty, of the Federal Machine & Welder Company, will give a talk on the latest developments in resistance welding.

The February meeting will be held on the 19th. This meeting will be a joint meeting with the Detroit Safety Council and will be held at Masonic Temple. Mr. J. C. Hodge, Metallurgist, Babcock & Wilcox Company, will talk on "Grade A Welding."

NEW YORK

The January meeting of the New York Section was held as a joint meeting with the Metropolitan Section of the American Society of Mechanical Engineers. The program included a discussion of the new welding rules of the A. S. M. E. Boiler Construction Code, which represents a joint undertaking by the two societies.

The program included: "The Practical Application of the A. S. M. E. Welding Code," by A. J. Moses, Plant Superintendent, The Hedges-Walsh-Weidner Co., Chattanooga, Tenn.; "Meeting the Requirements of the A. S. M. E. Welding Code by the Shielded Arc," by J. C. Lincoln, Lincoln Electric Co., Cleveland, O.; "The Effect of the New Welding Code on Process Industries and the Importance of Its Proper Application," by F. G. Sherbondy, Vice-President, The Biggs Boiler Works Co., Akron, Ohio.

The February meeting of the New York Section will be held on February 9th as a joint meeting with the Metropolitan Section of the American Society of Civil Engineers. The meeting will be given over to the report of the Structural Steel Welding Committee of the American Bureau of Welding.

Few investigations have assembled and coordinated such a vast amount of practical data for the designing and construction engineer. Five years were required for its completion and it represents the cooperation of three rolling mills, 39 fabricating shops, 61 welders, 18 inspectors and 24 testing laboratories.

The program includes: "Significance and Importance of the Report," by L. S. Moisseiff, Chairman of the Structural Steel Welding Committee; "Aims of the Investigation," by F. T. Llewellyn, member of the Structural Steel Welding Committee and a representative of the A. S. C. E.; "Results of the Tests and Recommendations of the Committee," by H. M. Priest, Vice-Chairman of the Committee; "Practical Applications to Steel Structures," by F. P. McKibben, Consulting Engineer, Member of the Committee.

NORTHERN NEW YORK

The first meeting of the season of the Northern New York Section was held on December 3rd, when Mr. Chapman of the Lukenweld Corp. delivered a talk before approximately two hundred people.

The second meeting will be held early in February at the Rensselaer Polytechnic Institute in Troy, N. Y. The date has not as yet been settled.

PITTSBURGH

C. G. Watson, General Manager, Youngstown Welding & Engineering Company, in his paper on "Standardization" presented December 16th, before the monthly meeting of the Pittsburgh Section of the American Welding Society, discussed at length some of the reasons why the application of the welding processes has not progressed more rapidly in the metal working industry. Mr. Watson discussed ways and means that should be employed to establish definite standards, rules and ethics. He stated this must be done in order to lay down principles by which one may specify, purchase and judge welded products and eliminate the uncertainty now felt when considering welding.

A. A. Chambers, Metallurgist, Tube Division, Youngstown Sheet & Tube Company, showed two reels of motion pictures depicting "The Laying of 200 Miles of 26-Inch Diameter Pipe through Kansas." The pipe, which of itself was arc welded, was joined together by the same process. The pictures showed a very novel method of bending a section of pipe so that it would conform with the contour of the trench. Experience proved that it was cheaper to heat and bend the pipes than it was to level, by hand, the trench so that the pipe would lay level. The speaker was of the opinion that all future pipe lines will be fabricated by welding.

The January meeting of the Pittsburgh Section will be a joint meeting with the Local Chapter of the American Society of Mechanical Engineers to be held the thirteenth of the month at the William Penn Hotel. The speaker for this meeting will be J. C. Hodge, of the Babcock and Wilcox Company, who will present a paper on "The Welding of Pressure Vessels."

SERVICES AVAILABLE

A-152. Structural engineering sales executive, experienced in designing structural steel and ornamental iron for both riveted and welded construction; experienced in estimating, costs, burden application and sales. Available April 1.

A-153. Welding Engineer, experienced in quality shopwork, inspection, can cooperate with engineering department for developing correct design for economical welding. Invites employment for limited period.

A-154. Desire position as foreman or welder. Am willing to go anywhere. Can talk Spanish, German, Italian. Have had experience in breaking in new men. Have also specialized in promoting welding of alloys. Can furnish references. Am forty years of age and married. Have had experience as boiler maker, welder with such companies as Robins Dry Dock and Repair Company, Electric Welding Company of America, Cole & Duncan Boiler Works, Western Welding & Equipment Company, Mojonnier Bros. Co. and M. W. Kellogg Company.

Outstanding Welding Developments in 1931

✦Compiled by the Meetings and Papers Committee of the American Welding Society.

Introduction

Each year the Meetings and Papers Committee of the American Welding Society assembles material for a review of the outstanding welding developments during the past year. There is of necessity some overlapping of material reported in the previous year as in many instances it is not feasible to separate the developments of one year from that which took place in the previous year. The Committee acknowledges its indebtedness to other individuals than those composing its own membership. No claims are made for originality of the material contained in this report.

A Classic in Technical Society Research

The outstanding feature in the development of welding in 1931 was the presentation of the Structural Steel Welding Committee's Report epitomizing a five years' program of study and tests of various types of welded joints. The scope and thoroughness of the committee's work are so outstanding as to demand the attention of architects and engineers interested in steel construction. These results of the American Bureau of Welding's effort are now available in book form in the American Welding Society's office and constitute an engineering classic. Commenting editorially on the report the *Engineering News-Record* referred to it as the "Magna Charta of Structural Steel Welding."

The Program. Of 2493 steel specimens, welded by 61 welders at 39 fabricating shops and inspected by 18 inspectors, 1098 were made and tested to determine the competency of welders, who, after thus qualifying, proceeded to weld 1395 specimens for use in the final investigation. Twenty-four laboratories, including college and commercial institutions as well as the United States Bureau of Standards, tested the specimens for quality and strength.

Structural Steel Welding Committee's Major Conclusions. Outstanding results of this unusually comprehensive research are:

1. No harmful effect on the base metal due to welding was disclosed.

2. For designing welded joints in buildings subjected to quiescent loads, the unit stresses permitted in the American Welding Society's "Code for Fusion Welding and Gas Cutting in Building Construction" are safe and reasonable; and are endorsed, provided welders be qualified.

These permissible unit stresses are, in pounds per square inch of weld throat, 11,300 shear, 13,000 tension, 15,000 compression.

3. Since these tests on 2493 specimens made in 39 shops indicate that joints commercially welded by qualified welders may be expected to possess strengths within 12 per cent of general average results, engineers and architects may feel secure in expecting, in their completed structures, the strengths required by their drawings.

4. In general, regardless of geographical location, the results reveal striking similarity between each welder's qualification and final tests.

Structural Steel Welding and Cutting

Not only is the increase in number of applications of welding to steel buildings of interest, but the increase in size of structures to which this process is being applied is also notable. A survey of existing steel structures in the United States, wholly or partially welded, reveals 46 bridges and 183 buildings in which welding was used as a means of fabricating the steel frames.

Prior to the year 1931 very few data were available for use in making preliminary estimates for the amount of welding in a steel building frame and the time required to perform the welding. But recently some accurate records have been kept and are now accessible.

Welding and the Building Codes. During the year ending December 15, 1931, twenty-one towns and cities incorporated in their building codes, provisions for welding steel building frames, making a total of 114 municipalities, which had taken such action. New Orleans, with a population of 456,000, is the most populous in the list. New York City's proposed building code includes provision for welding, but this code has not yet been adopted.

Ornamental Metal Work. Current developments in the creation of oxy-acetylene welded ornamental metal products have seen the final passing of obvious imitations of the blacksmith's handiwork and the gradual growth of the independent craft with a true artistic background.

This industry now has available creative artists and a wide variety of pressed units such as sections, motifs and conventional designs in addition to artisans capable of molding, casting or hand hammering almost any shape or design for assembly with the oxy-acetylene torch into graceful creations whether a piece of furniture, a lighting fixture, a rail or gate or specific ornament to be attached to a stone or masonry structure.

Metals now being used for this purpose include steel, wrought iron, brass, bronze, copper, aluminum, stainless steels and some newly developed alloys. These metals are finished in a wide range of effects varying from the antique to the ultra modern including black and white contrasts or any desired lacquer finish.

Demolition of Buildings. The last year or so has seen the demolition of a score of steel frame office buildings considered skyscrapers when erected less than 25 years ago, and an almost equal number of substantially built power houses, hotels, theatres and apartments have likewise been torn down. Some of these buildings were 25 stories high and occupied such valuable property that high daily bonuses and penalties were attached to the wrecking contract. The cutting torch has been largely responsible for the remarkable progress made in demolition work as it possesses the flexibility to meet the demands of speed and unusual working conditions.

Pressure Vessels and Boilers

Of importance comparable to the Structural Steel Report referred to above are the new rules adopted in July by the A. S. M. E. relating to the welding of Unfired Pressure Vessels and Boilers. These rules promulgated in cooperation with the American Welding Society came about after several years' technical investigation, discussion and gradual broadening of existing rules.

The new code under certain restrictions opens the way for the use of welding on all unfired pressure vessels and boilers regardless of size or operating pressures.

The code is graduated so that there are three classes of tanks provided for in which the test requirements control the degree of quality required and the consequent allowable stress in the welded joint.

Class 1 provides for any type or size of vessel without restriction as to use, but to compensate for this, very exacting construction and test requirements are specified including heat treatment of the completed vessel for stress relief and non-destructive X-ray tests of the completed joints on each vessel.

Class 2 carries limitations as to shell plate thickness, working pressure and working temperatures, the maximum plate thickness provided for being $1^1/_2$ in. No non-destructive test is required for this class of vessel and heat treatment for stress relief is required only on thicker walled vessels.

Class 3 carries still further limitations as to size and use, the maximum plate thickness being $^5/_8$ in. For this class of tank, no stress relief or non-destructive tests are required.

The requirements for welded steam boiler drums are identical with those for Class 1 Unfired Pressure Vessels.

Pipe Line Welding

There have been further improvements in this field along the lines reported last year, namely, in procedures which materially cut down the time of welding.

In the oxy-acetylene welding of pipe lines, costs of welding have been materially reduced by the making of narrower welds with improved rods and an improved method of welding technique.

The new technique consists of the application of the carburizing flame process. The sides of the welding Vee, which has a preferred included angle of about 60 degrees, are not broken down but are raised to the sweating temperature only, and a welding rod of suitable alloy is fused into the Vee with very little manipulation of the torch or rod. Welders learn the new technique quickly, and naturally like it as the welding effort is reduced when compared with the ordinary puddle welding technique. Pipe welds made by this process are of high tensile strength and free of pinholes and porosity.

In the arc welding of pipe lines the principal developments have been in the use of new electrodes permitting higher welding speeds with no reduction in quality.

Several thousand miles of pipe for various purposes including steam lines have been welded during the past year by these processes.

Machinery Construction

The use of welded steel in machinery construction advanced very rapidly during the past year. An increasing number of companies have gone to the use of cutting and welding in the construction of their machinery.

Some fundamental investigations have been made on methods of avoiding concentration of stresses and the minimizing or relief of these stresses in this construction work.

Welded Tanks

Copper or copper alloy tanks are much in demand in the chemical industries and for hot water heaters and storage. Since it resists corrosion so much better, the shell walls are made thinner than is the case with steel. This means that all seams and connections are desired with an unusually high efficiency which can be attained only by welding.

Equal progress has been made in the welding of the stainless and heat resisting alloys.

Automotive Industries

Cross members for large automobile frames are now made of two stamped channels and welded together on two edges at once, each seam being from 36 in. to 40 in. long and the two welds being made simultaneously by the flash process in about five seconds. The resulting cross member can be twisted around and around like a rope until the base metal itself ruptures without any failure of the welds.

Another recent development is the use of resistance welding by the flash process for the making of automobile dies for punching out body stampings. The cutting edge or shoe is high carbon steel and the shank is mild steel and the shoe is now welded on to the shank in sections sometimes as great as 60 square inches. Best results are obtained when both the high carbon member and the mild steel member are each heated up to about 1800 or 2000° F. before the welding is done. By this method it is not necessary to anneal the high carbon member after welding, as the heat remaining in the piece anneals it sufficiently.

Numerous smaller jobs have been developed where enormous savings have been made by the resistance welding process, as, for instance, in automobile starter gear rings. It was formerly the practice to put the teeth of the starter ring right on the flange of the flywheel. This meant that the teeth would be ordinary cast iron and when once stripped, they required an entirely new flywheel. Now it is the practice to roll them up out of high carbon steel, weld them, cut the gear teeth on them and shrink them on to the flywheel. This is being done by welding at the rate of 12 rings per minute per welder.

The heavy duty full automatic spot welder has come into use very generally during the last year for welding together frames and frame members for various types of automobiles. Furthermore, in certain makes of automobiles the hubs are now made from two stampings and are then spot welded or projection welded together and the wire spokes are then welded in from hub to rim as the final operation.

A rather extensive use for the oxy-acetylene cutting process has been built up in the scrapping of old cars. Numerous establishments for the scrapping of cars and resale of used parts have been opened in various parts of the country and the use of the process in this work has been increasing constantly.

Hard Facing

Great interest has been shown during the past year in the use of hard-facing materials in reclamation, repair and production work. Severe abrasion conditions have been overcome and considerable savings effected by covering parts subjected to the greatest wear with a layer of hard-facing material that will outwear ordinary steels many times. Cement mills, brick plants, steel mills, oil fields, mines, quarries, excavator equipment, farming tools and aircraft tail skids are all fields in which hard-facing has been used with splendid success.

In the oil fields this process has almost completely dominated the field of hard-surfacing bits. The Ameri-

can Petroleum Institute has issued a code of recommended practice for the guidance of bit smiths and welders.

Plumbing, Heating and Steam Fitting

Welding in these fields has advanced tremendously during the past year.

The large contributing factor to this development is that the large plumbing and heating supply companies have added a new line to their supplies in welding fittings of every design and shape. Contractors can now competitively purchase any kind of a welding fitting that he could formerly purchase for a screw fitted pipe installation.

There are now eight large old reliable supply companies with welding fittings as regular stock which include two companies carrying complete lines of welding fittings and six carrying partially complete lines or a highly specialized fitting.

The year 1931 witnessed one of the largest welded piping installations ever made—the Cornell Medical Centre group of buildings, in which over 70 miles of welded piping for steam, water and brine transmission have been installed.

Many miles of 6 in. to 12 in. pipe for high and low pressure steam have been welded in the New York Hospitals at Central Islip and Brentwood.

The welding fittings now available are turns, elbows, saddles, sleeves, caps, reducers, 45° ells, 90° ells, welding neck flanges, tees, 180° return bends, expansion joints, both single and double, and flange fittings with a welding neck. Another contributing factor is that these welding fittings are also available in wrought iron as well as steel.

In the welding of steam pipe lines for power piping developments within the past year have completely changed the welding methods and technique from the old standard practice previously in use, and it is now possible, with the newer methods and technique, to complete welds in much faster time, without sacrificing quality. This has resulted in many additional economies to the contractors.

There has been more activity and progress made in pipe welding the past year than in any previous year.

Railroad Welding

This year has witnessed the construction of several all-welded coal cars with resultant economy in construction, increase of capacity and improvement in design.

Another major operation which has found increasing use on the railroads is that of building up locomotive piston heads with manganese bronze. A total of 2213 heads were reclaimed by one railroad with this process. An important feature of this process is the reduced wear on the cylinder bushings resulting from the bronze surface of the head. Service tests have proven that a piston head built up with bronze will outwear approximately three of the regular cast iron heads and this operation can be done at 50% less cost than that of applying a new head.

With the aid of automatic shape-cutting machines and welding, complete locomotive frames are now being fabricated including front breast beams, cross ties, brake hangers, rear decks, etc. The first costs of such welded frames are comparable in every way to former methods of manufacture; however, in such cases the real savings effected are by the complete elimination of maintenance of all connections and splice bolts, including bolted brackets.

Marine

Probably the largest progress of welding in the marine field has been in the acceptance of the welded joint for piping. A number of major vessels have been constructed with the largest part of the piping systems entirely oxy-acetylene welded, these including passenger vessels, as well as cargo carriers, tankers, ferryboats and smaller craft. The new scout cruisers being built for the United States Navy are designed to include a large amount of welded construction. This has permitted the designers to achieve greater efficiency with the same gross tonnage, an end greatly to be desired in this type of vessel.

Gas Cutting

Billet skinning and de-seaming in steel mills with the oxy-acetylene cutting torch fitted with special tips, have been developed during the year to the point where the operation is accepted as economical as compared with air hammer chipping or machine planing.

Welding of Metals

Steel. During 1931 a Sub-Committee of Committee A-1 of the American Society for Testing Materials adopted a list of standard A. S. T. M. Steel specifications for steels which in their opinion were of satisfactory qualities for fusion welding. Included in this list are: structural steel for bridges, buildings, locomotives, cars and ships; boiler and firebox steel for locomotives and stationary service; steel plates of structural quality for forge welding; steel plates of flange and firebox quality for forge welding; welded and seamless steel pipe; cold-drawn steel wire for concrete reinforcement; lap-welded and seamless steel pipe for high temperature service; black and hot-dipped zinc-coated (galvanized) welded and seamless pipe for ordinary uses; and open-hearth iron plates of flange quality. This is an important step in the progress of welding, as it provides a variety of steels of different chemical compositions which are recommended as suitable for fusion welding by this authority on materials.

Copper and Brass. Several new uses of the welding of copper and copper alloys have been developed during the past year. The welding of copper or brass tubing to various types of headers of cast iron, steel, malleable iron, bronze, brass and other copper alloys has gained considerable impetus. More and more brass and copper tubing is being installed by welding for plumbing installations in domestic and industrial piping.

There has been an increased demand by the chemical industry for hot water heaters and storage tanks of copper and copper alloys. As the shell walls are thinner than is the case with steel, all seams and connections are required to have an unusually high efficiency which can be attained only by welding.

Certain copper alloys which can be extruded into special shapes for metal window frames and sashes have been extensively used during the past year. Most of the material for this work is of a high-zinc, high-lead composition, and a yellow bronze-welding rod is used in order to match the color. White Benedict nickel and a high-copper alloy with a small percentage of manganese and silicon are also being used for extruded shapes and welded with rods of suitable composition.

Stainless and Heat-Resisting Alloys. Manufacturers have spent considerable effort to assure good welding quality in stainless and heat-resisting alloys. The majority of the alloys now on the market can be placed

in six groups with regard to their percentages of carbon, chromium, silicon and nickel, and practically all of these alloys can be welded successfully. A large number of alloy castings which are not ductile even as cast are also being welded with excellent results, provided the correct welding procedure is used. In many cases it is necessary that the casting be heat-treated after welding so that the maximum resistance to either heat or corrosion will be obtained, and the strength and ductility of the casting will be improved.

Welding and Cutting Apparatus

Gas Welding and Cutting Apparatus. For ordinary methods of oxy-acetylene welding, the past year has seen a marked tendency to develop blowpipes or torches especially designed for a single type of work. The old-time welding shop's single heavy torch with a few different sizes of tips has largely given way to an assortment of blowpipes or torches for welding everything from sheet metal to heavy castings.

Accessories include such devices as cutting attachments, detachable valve bodies with which several different blowpipe or torch handles can be used, welding and cutting tip adaptors, extension tubes, swaged or separable tips and tips especially designed for unusual kinds of work.

Another striking evidence of progress has been the development of a blowpipe or torch appliance for use with a new welding method which more than doubles welding speeds. This new equipment makes pipe and plate welding a semi-automatic process and produces high-quality welds at remarkably low cost.

In oxy-acetylene cutting, the development of portable shape-cutting equipment and semi-automatic hand guides for cutting blowpipes or torches has made it possible for shops not equipped with full-sized shape-cutting outfits to do this type of work. The pocket-sized cutting attachment also has done much to broaden the utility of oxy-acetylene cutting.

In certain industries, the importance of mechanical cutting, as it is woven into the general production scheme, has justified the development of cutting machines possessing increased speed and efficiency. The latest developments along this line comprise cutting machines with multiple torch operation, centrally controlled from the operator's station. The control includes automatic lighting of the torches.

Arc Welding Machines. The past year has seen the general introduction of direct current generators of a materially improved design. As a result of these characteristics the arc is much more easily manipulated and very much superior welds can be produced.

One hundred amp. arc welding sets have been put on the market for sheet metal and other light gage welding.

Another striking innovation is the commercial introduction of an alternating current arc welding transformer equipped with a high frequency oscillating circuit designed to discharge between the electrode and the work. With the proper type of oscillator the A.C. arc characteristics are improved to such a marked extent that many operators consider it easier to handle than a direct current arc.

Resistance Welding Machines. Machines have been put in service for continuously flash welding the longitudinal seams in pipe 20 inches in diameter and $^{5}/_{16}$ inch or more in thickness at speeds of 35 to 40 feet per minute. Skelp is formed from flat plate also continuously at the same rate as the welding speed so that the entire process is continuous. Such machines require an input of about 1200 kw.

Other machines have been developed for this same purpose but solving the problem in a somewhat different manner. In these cases the entire length of pipe, say, 36 feet, is flash welded simultaneously by a number of welders operating in parallel, each supplying current through contact shoes to weld a three foot section. A machine of this type requires approximately 11,000 kv-a of power for operation and will weld a pipe 24 inches in diameter, $^{1}/_{2}$ inch thick in approximately one minute.

Spot welding during the last year has gone to greater capacities and sizes than was ever dreamed of before and these are mostly of the heavier duty type, and completely automatic. Such welders have been made in large numbers in 100 kv-a to 800 kv-a capacities. The 800 kv-a capacity spot welder will make a spot 1 inch wide x 4 inches long, or 4 square inches. They have adjustable lower horns, that is, for adjusting the distance between the upper and lower horns, and are made with pick-off gears so that four different speeds may be obtained as may be required for different classes of work. The reciprocating parts of these large heavy duty welders are so heavy that it is necessary to use air cylinder and tank on top of the machine to raise the head from the spot between welds. This cylinder and tank has nothing to do with the pressure on the weld as that is taken care of by gear box and cam and toggle on the interior of the welder housing itself.

The art and practice of projection welding has gone forward by leaps and bounds during the last year. The greater part of the development has been in connection with very heavy duty and very large types of welders.

For example, one of these modern projection welders will weld either 10 medium size projections around shell hubs, or five large projections as the case may require. In either instance the machine draws about 3000 kv-a power per weld, indicating that it requires about 300 kv-a for each of the small projections and about 600 kv-a for each of the large projections, which are about $^{3}/_{8}$ inch diameter.

It would seem at the present writing that the only limit to the size and power of electric welders is the amount of power available that the power companies will be able to furnish to customers for welding purposes.

The use of the thyratron tube for interrupting the current in resistance welding machines is a new development which promises greater accuracy of control than mechanical interruptors for certain types of machine.

Welding Wire

For arc welding there have been put on the market special coated and covered electrodes, and other methods of shielding the arc, which permit higher speeds in welding with improved quality of weld both as to ductility and strength. Reference has been made to this development under the head of pipe welding and also in connection with Grades A and B welding in the Pressure Vessel Code of the A. S. M. E. A number of special welding rods have also appeared on the market for the gas welding of steel, copper, aluminum and brass alloys.

Welding Contractors and Welding Shops. One of the greatest advances in the field of contract welding shops has been the fact that they are establishing themselves on a firm business foundation and are becoming of greater value to local industries in offering facilities not only for repair, but also in many cases for production welding on a routine basis. Standards for workmanship

have been set up in various localities by meetings of the welding contractors, and these tend to place the contact welding shops on a sounder and more profitable footing.

Value of Welding Machinery

The U. S. Department of Commerce Bureau of the Census states that during the year 1929 the value of welding machinery and apparatus manufactured as reported to the Bureau was $13,582,949.

Progress in Other Fields

Considerable progress and advance in welding and cutting has been made in a number of other fields not included in this report among which may be mentioned sheet metal welding, welding of non-ferrous metals, aluminum and welding and cutting in manufacturing and construction in such fields, as steel mills, chemical industry, oil industry, steam railroads and electric railways, highways and aircraft.

Rules for Fusion Welded Construction of Boilers and Pressure Vessels*

Editor's Note: Our readers will no doubt recall publications of preliminary drafts of the proposed new rules for fusion welding that appeared in the March, 1930, and January, 1931, issues of the A. W. S. JOURNAL. *These drafts represented the results of an intensive study of the question of welded construction by the A. S. M. E. Boiler Code Committee in cooperation with our Society. The attempts to codify fusion welded construction induced much discussion and some criticism, but the Committee finally succeeded in agreeing upon rules for the welding of both boilers and pressure vessels, which are here published for the benefit of those that have followed this work.*

It is interesting to note that while in the early stages of this development an attempt was made to control the quality of the welded work by specifying the mode of its application, such as by procedure control or otherwise, the new rules quoted herein make no reference to the method or process of applying the welding, and undertake to regulate the quality of the welding only by critical tests of the finished product. This marks the introduction of a new era in the control of welded construction, which will no doubt be reflected into other channels of welded construction. This method is obviously much more practical than the methods heretofore proposed, including procedure and the like, and will undoubtedly lend itself to much more extensive use of fusion welding, as there now will be no restrictions but rather encouragement of special and proprietary processes. In other words, this method lends encouragement to the highest development of welding as exemplified in ductility of deposited metal, complete penetration, thorough fusion, etc.

The rules for welding of pressure vessels are divided into three classes, based upon the intended use of the vessel. Class 1, which represents the highest type of construction, is absolutely without limit as to size, working pressure, or the contents; the requirements for this class, which are identical with those for construction of steam boiler drums, contain the most rigid safeguards relative to the application of the welding process. Class 2 provides for vessels with a maximum plate thickness of $1^1/_2$ in., which are not to carry lethal gases or liquids, or be subjected to as severe conditions of service as those built under Class 1; such vessels must not carry liquids at a temperature of 300° F. or above, and the maximum operating pressure and temperature in this class are 400 lb. per sq. in. and 700° F. Class 3 provides for vessels with a maximum plate thickness of $^5/_8$ in., which are not to carry lethal gases or liquids, or be used for the storage of gases or liquids at any temperature materially exceeding their boiling temperature at atmospheric pressure; the maximum pressure and temperature permitted in this class are 200 lb. per sq. in. and 250° F.

The new rules for welded pressure vessel construction only are here reproduced for the information of our members. The rules for welding steam boiler drums are as above noted, identical with the rules for Class 1 pressure vessels. In addition there are special rules for the welding of miniature boilers, but these are identical with those for Class 2 pressure vessels. Accordingly the two latter groups are not here reproduced.

These new welding rules were brought to completion by the joint action of the Boiler Code Executive Committee and the A. W. S. Conference Committee, who presented their final report to the Boiler Code Committee at its June meeting. Subsequent to this, the revised rules were reported to and adopted by the Council of the A. S. M. E. on July 7, 1931, which renders them effective in so far as the joint work of the Societies is concerned. It is reported that several of the states are now studying these new rules with a view to adopting them for enforcement together with the existing code rules.

Addenda to A.S.M.E. Boiler Code—Unfired Pressure Vessel Section

U-23. Pressure vessels may be fabricated by means of fusion welding under the rules given in Pars. U-67 to U-79, provided the construction is in accordance with the requirements for material and design as required by this code and the fusion welding process used conforms to the specifications for the welding indicated for each class of vessel.

The Following Paragraphs Replace Present Pars. U-67 to U-79 and UA-10 to UA-21

Rules for the Fusion Process of Welding

U-67. Pressure vessels may be fabricated by means of fusion welding provided the construction is in accordance with the requirements for material and design as required by this Code and the fusion welding process used conforms to the specifications for each class of vessel.

Definitions: (*a*) *Fusion Welding.* A process of welding metals in the molten, or molten and vaporous state without the application of mechanical pressure or blows.

(*b*) *Fillet Weld.* A fusion weld of approximately tri-

* Recently adopted by the A. S. M. E.

angular cross-section whose throat lies in a plane disposed approximately 45 deg. with respect to the surfaces of the parts joined.

(*c*) *Throat.* The minimum thickness of a weld along a straight line passing through the bottom of the cross-sectional space provided to contain a fusion weld.

(*d*) *Double-Welded Butt Joint.* A joint formed by the fusion of two abutting edges with a filler metal added from both sides of the joint and with reinforcement on both sides.

(*e*) *Single-Welded Butt Joint.* A joint formed by the fusion of two abutting edges with all the filler metal added from one side of the joint with a reinforcement on the side from which the filler metal is added.

NOTE: A joint with filler metal added from only one side is considered equivalent to a double-welded butt joint when and if means are provided for accomplishing complete penetration and reinforcement on both sides of the joint.

U-68. *Class 1.* All vessels covered by this Code, constructed in accordance with the rules herein given, may be used for any purpose.

The joint efficiency E for this class to be used in applying the rules in Par. U-20 shall be taken as 90 per cent.

Welding for this class shall meet the following test requirements:

(*a*) *Test Plates for Longitudinal Joints.* Two sets of test plates of the dimensions shown in Fig. U-7 from steel of the same specifications as the shell plates, prepared for welding, may be attached to the shell plate being welded, as in Fig. U-6, one set on each end of one longitudinal joint of each vessel so that the edges to be welded in the test plates are a continuation of and duplication of the corresponding edges of the longitudinal joint. In this case the weld metal shall be deposited in the test plates continuously with the weld metal deposited in the longitudinal joint. As an alternate method, detached test plates may be welded as provided for in (*b*).

(*b*) *Test Plates for Circumferential Joints.* When test plates are welded for the longitudinal joints, none need be furnished for circumferential joints in the same vessel provided the welding process, procedure and technique are the same. Where a vessel has only circumferential joints, two sets of test plates of the same material as the shell shall be welded in the same way as the joints in question.

(*c*) The test plates shall be so supported that warping due to welding shall not throw the finished test plate out of line by an angle of over 5°.

Where the welding has warped the test plates, they shall be straightened before being stress relieved. The test plates shall be subjected to the same stress-relieving operation, as required by Par. U-76. At no time shall the test plates be heated to a temperature higher than that used for stress relieving the vessel.

(*d*) *Test Specimens.* The inspector shall select one of the two welded test plates, from which the coupons for tension and bend tests and for specific-gravity determinations shall be removed as shown in Fig. U-7 and be of the dimensions shown in Figs. U-7 and U-8.

(*e*) *Tension Tests.* Two types of tension-test specimens are required, one of the joint and the other of the weld metal. The tension specimen of the joint shall be transverse to the welded joint, and shall be the full thickness of the welded plate after the outer and inner surfaces of the weld have been machined to a plane surface flush with the plate. When the capacity of the available testing machine does not permit testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall meet the requirements.

The tensile strength of the joint specimen in Fig. U-7 shall not be less than the minimum of the specified tensile range of the plate used.

The tension-test specimen of the weld metal shall be taken entirely from the deposited weld metal and shall meet the following requirements:

Tensile strength = at least that of the minimum of the range of the plate which is welded.

Elongation, minimum = 20 per cent in 2 in.

For plate thicknesses less than $^5/_8$ in., the all-weld-metal tension test may be omitted.

(*f*) *Bend Tests.* The bend-test specimen shall be transverse to the welded joint of the full thickness of the plate and shall be of rectangular cross-section with the width $1^1/_2$ times the thickness of the specimen. When the capacity of the available testing machine does not permit testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall meet the requirements. The inside and outside surfaces of the weld shall be machined to a plane surface flush with the plate. The edges of this surface shall be rounded to a radius equal to 10 per cent of the thickness of the plate. The specimen shall be bent cold under free bending conditions until the least elongation measured within or across approximately the entire weld on the outside fibers of the bend-test specimen is 30 per cent.

When a crack is observed in the convex surface of the specimen between the edges, the specimen shall be considered to have failed and the test shall be stopped. Cracks at the corners of the specimen shall not be considered as a failure. The appearance of small defects in the convex surface shall not be considered as a failure if the greatest dimension does not exceed $^1/_{16}$ in.

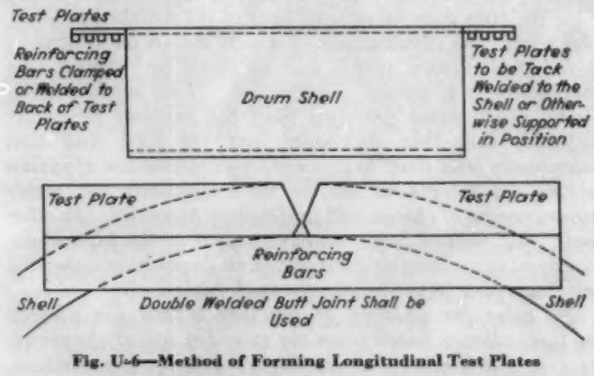

Test Plates
Reinforcing Bars Clamped or Welded to Back of Test Plates
Drum Shell
Test Plates to be Tack Welded to the Shell or Otherwise Supported in Position
Test Plate
Test Plate
Reinforcing Bars
Shell
Double Welded Butt Joint Shall be Used
Shell

Fig. U-6—Method of Forming Longitudinal Test Plates

(*g*) *Specific Gravity of Weld Metal.* Specimens shall be taken from the weld metal of the joints. The specific-gravity specimens shall, if possible, be 2 in. long and $^5/_8$ in. in diameter, as shown in Figs. U-7 and U-8. The minimum specific gravity shall be 7.80.

(*h*) *Retests.* Should any of the tests other than the specific-gravity tests fail to meet the requirements by more than 10 per cent, no retests shall be allowed.

Should any of the tests other than the specific-gravity tests fail to meet the requirements by 10 per cent or less,

retests shall be allowed on specimens cut from the second welded test plate.

The retests shall comply with the requirements. For either of the tension retests, two specimens shall be cut from the second test plate, and both of these shall meet the requirements.

When there are more than one specimen of the same type and when one or more of the group specimens fail to meet the requirements by 10 per cent or less, the retest shall be made on an entire group of specimens, which shall meet the requirements.

Should the specific gravity obtained on the specific-gravity specimen be less than 7.75, no retest shall be allowed. Should the specific gravity lie between 7.75 and 7.80, a retest shall be allowed. The retest shall show a specific gravity of not less than 7.80.

(*i*) *Non-Destructive Tests of Vessel.* For plate thicknesses $2^1/_2$ in. and less, every portion of all longitudinal welded joints and of one circumferential welded joint, or one circumferential welded joint where there is no longitudinal joint, of the structure shall be radiographed by a sufficiently powerful X-ray apparatus under a technique which will determine quantitatively the size of a defect with a thickness greater than 2 per cent of the thickness of the base plate. The X-ray films shall be submitted to the inspector. Vessels of a wall thickness over $2^1/_2$ in. need not be X-rayed until such a time as evidence is submitted to the Boiler Code Committee that the X-ray or similar means are developed that can be commercially applied to greater thickness. Any

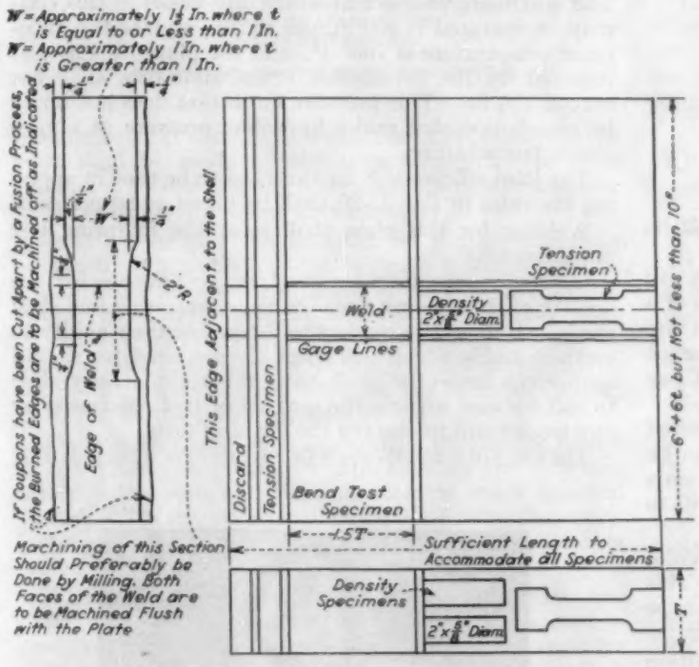

W = Approximately 1½ In. where t is Equal to or Less than 1 In.
W = Approximately 1 In. where t is Greater than 1 In.
If Coupons have been Cut Apart by a Fusion Process, the Burned Edges are to be Machined off as Indicated
Edge of Weld
This Edge Adjacent to the Shell
Discard
Tension Specimen
Bend Test Specimen
Weld
Gage Lines
Tension Specimen
Density 2"x⅝" Diam.
6"+6t but Not Less than 10"
1.5T
Sufficient Length to Accommodate all Specimens
Density Specimens
2"x⅝" Diam.
Machining of this Section Should Preferably be Done by Milling. Both Faces of the Weld are to be Machined Flush with the Plate

Fig. U-7—Test Specimens from Longitudinal Welded Test Plates

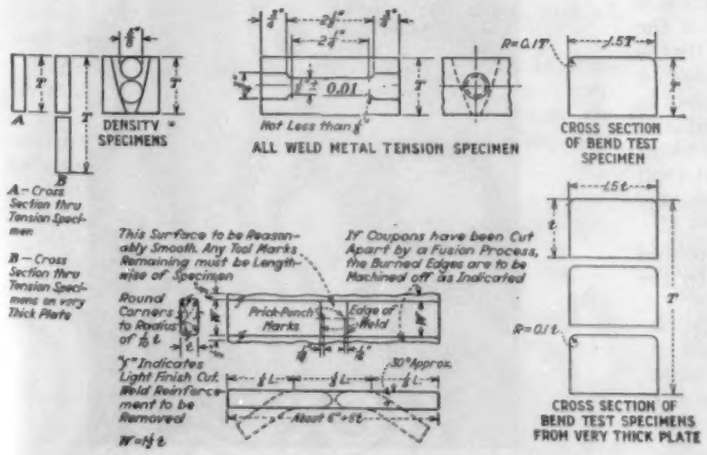

DENSITY SPECIMENS
A
B
A—Cross Section thru Tension Specimen
B—Cross Section thru Tension Specimens on very Thick Plate
ALL WELD METAL TENSION SPECIMEN
Not Less than ⅝"
CROSS SECTION OF BEND TEST SPECIMEN
1.5T
This Surface to be Reasonably Smooth. Any Tool Marks Remaining must be Lengthwise of Specimen
If Coupons have been Cut Apart by a Fusion Process, the Burned Edges are to be Machined off as Indicated
Round Corners to Radius of ⅛ t
Prick-Punch Marks
Edge of Weld
30° Approx.
"F" Indicates Light Finish Cut. Weld Reinforcement to be Removed
About 6"+5t
W=½ t
CROSS SECTION OF BEND TEST SPECIMENS FROM VERY THICK PLATE

Fig. U-8—Details of Test Specimens

Radiograph No. 1—Excellent or Ideal Weld

Radiograph No. 2—Porous But Acceptable Weld

Radiograph No. 3—Porous and Unacceptable Weld

defects repaired after the X-ray examination shall be again X-rayed.

A manufacturer shall demonstrate his ability to produce sound welds by constructing Class 1 vessels of a thickness not less than 2 in., the joints of which are X-rayed, in order to be permitted to construct Class 1 vessels with a shell thickness over $2^1/_2$ in. without X-ray examination.

Radiograph No. 1 of Fig. U-9 shows the desired type in which the presence of the welded joint can be detected only with great difficulty. This type represents excellent weld metal with a specific gravity of 7.80 to 7.85.

Radiograph No. 2 of Fig. U-9 shows the presence of some porosity of the weld metal in the joint. This porosity, however, is not excessive, and welds of this type shall be acceptable.

Radiograph No. 3 of Fig. U-9 shows a porous condition in the weld metal which is not acceptable.

Radiograph No. 4 of Fig. U-9 shows a serious defect in a welded joint. This defect represents a slag inclusion or cavity, extending longitudinally along the wall of the joint. A radiograph of this kind indicates a weld that is not acceptable. However, a radiograph showing a defect of this kind in which the length of the defect is less than $^1/_3T$, where T is the thickness of the joint and where these defects are separated from each other by at least $2T$ of solid weld metal, indicates a weld that shall be acceptable, provided such defects do not average more than one per foot for any one joint.

A description of the X-ray technique employed shall be submitted with the radiographic films to the inspector, this record giving:

1. The thickness of the plate.
2. The distance of the film from the rear of the joint.
3. The distance of the film from the source of X-rays.
4. The voltage impressed on the tube.
5. The current flowing through the tube.
6. The time of exposure.
7. The type of film used.
8. The type of intensifying screens.

The locations of the reference markers, the images of which appear on the film, shall be accurately and permanently stamped on the outside surface of the vessel near the weld, so that a defect appearing on the X-ray film may be accurately located in the actual welded joint.

To determine whether the X-ray technique employed is detecting defects of a thickness 2 per cent or greater than the thickness of the base plate, a piece of sheet steel of a thickness equal to 2 per cent of the base plate and containing a hole shall be placed alongside the welded joint so that its image is obtained on the X-ray film but still does not interfere with the image of the welded joint. The image of the hole in the sheet should be obtained on the X-ray film. Any approved equivalent method may be used.

U-69. *Class 2.* All vessels covered by this Code may be included in this class, excepting those containing lethal gases or lethal liquids and/or those containing liquids operating at a temperature of 300° F., or above. The maximum pressure at which any vessel in this class may be operated is 400 lb. per sq. in., and/or the maximum temperature is 700° F., and the plate thickness as required by the permissible stress allowance shall not exceed $1^1/_2$ in. This pressure limitation does not apply to vessels operated under hydraulic pressure at atmospheric temperature.

The joint efficiency E for this class to be used in applying the rules in Par. U-20 shall be taken as 80 per cent.

Welding for this class shall meet the following test requirements:

(a) Each manufacturer shall be responsible for the quality of the welding done by his organization and shall conduct tests of the welders to determine their ability to produce welds which will meet the required tests. An authorized inspector shall have the right at any time to call for and witness the making of test specimens by any welder and to observe the physical tests.

The tests of a welder shall be effective for a period of six

Radiograph No. 4—Defective Weld Along Wall of Joint—Not Acceptable

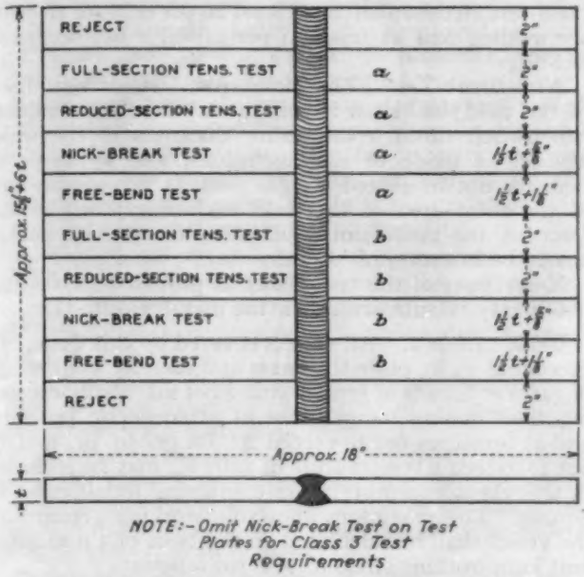


Fig. U-10—Test Plate Dimensions and Specimen Locations

months only, at the end of which time a repetition of the tests shall be made by the manufacturer. The tests conducted by one manufacturer shall not qualify a welder to do work for any other manufacturer.

Each welder shall be assigned by the manufacturer an identifying number, letter or symbol, which shall be stamped on all vessels adjacent to and at intervals of not more than 3 ft. along the welds which he makes either by hand or by machine, or a permanent record may be kept by the manufacturer of the welders employed on each joint, which shall be available to the inspector, and in such case the stamping may be omitted.

The manufacturer shall maintain a permanent record of the welders employed by him, showing the date and result of the tests and the identification mark assigned to each. These records shall be certified to by the manufacturer and accessible to the inspector. (A sample data report sheet appears on page 18.)

(*b*) *Test Plates.* Material for test plates shall conform to the specifications for the material to be used in constructing the unfired pressure vessel. The tests for welders shall be considered as applying only to such materials.

Two test plates shall be made; one of a thickness of $^5/_8$ in. and the other of a thickness of $1^1/_2$ in., and all specimens of each plate shall be tested.

Where the maximum thickness employed in construction under these Rules is less than the limit permitted in these test requirements, test plates of the maximum thickness for which approval is desired may be substituted for the $1^1/_2$ in. test plate.

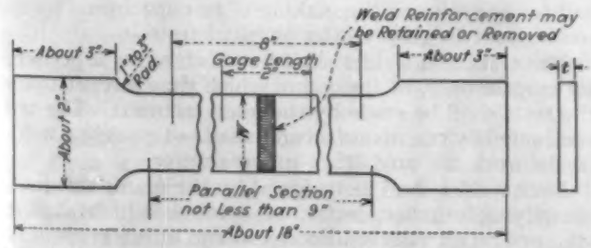


Fig. U-11—Full-Section Test Specimen Required for Tension Test of Welded Joint

Where these test requirements are to be employed for thicknesses less than $^5/_8$ in., a test plate of $^1/_4$ in. thickness shall also be made.

The required dimensions for the test plates and specimen location shall be as given in Fig. U-10.

Type of Joint. For these test requirements, the type of joint shall be the double-welded butt joint. The preparation of the edges of the test plate for welding shall be the same as to be employed in construction.

Procedure of Welding. The test plates shall be welded under the same procedure as to be employed for construction. The process of welding, size and type of welding rod, number of welding layers, position in which the welding is done, etc., shall be the equivalent of that to be used for construction. Only such accessories to or supplements of the welding procedure, for example, the employment of weld backing-up strips or reheating of the test plates for stress relief or heat treatment, shall be employed in the production of the test plates as will be required for construction.

The external appearance of the welds and the amount of weld reinforcement shall conform to the requirements for construction, and the maximum reinforcement for the test plates shall not exceed the minimum required for construction.

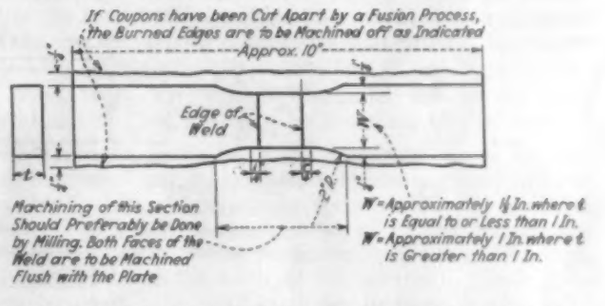

If Coupons have been Cut Apart by a Fusion Process, the Burned Edges are to be Machined off as Indicated
Approx. 10"
Edge of Weld
Machining of this Section Should Preferably be Done by Milling. Both Faces of the Weld are to be Machined Flush with the Plate
W = Approximately 1/4 In. where t is Equal to or Less than 1 In.
W = Approximately 1 In. where t is Greater than 1 In.

Fig. U-12—Reduced-Section Test Specimen Required for Tension Test of Welded Joint

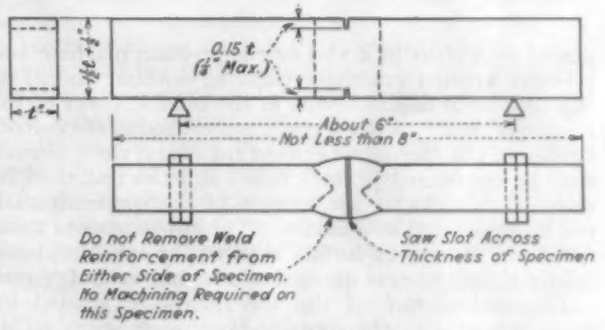

0.15 t
(3/8" Max.)
About 6"
Not Less than 8"
Do not Remove Weld Reinforcement from Either Side of Specimen. No Machining Required on this Specimen.
Saw Slot Across Thickness of Specimen

Fig. U-13—Specimen for Nick-Break Test

(*c*) *Test Specimens.* Two full-section tension-test specimens, two reduced-section tension-test specimens, two nick-break-test specimens and two bend-test specimens shall be required from each test plate.

Full-Section Tension-Test Specimen. The shape and dimensions of the tension-test specimen shall be as shown in Fig. U-11, with the weld at the center. Data shall be recorded on the ultimate strength and computed from the area of the base-metal section (pounds per square inch).

Reduced-Section Tension-Test Specimen. The shape and dimensions of the test specimen shall be as shown in

Fig. U-12. The top and bottom sides of this specimen should be machined to "clean up" the surfaces. The data to be recorded in connection with the reduced-section tension-test specimens shall be the same as for the full-section tension-test specimens.

Nick-Break-Test Specimen. The shape and dimensions of the specimen shall be as shown in Fig. U-13. The specimen is to be suitably supported as shown in Fig. U-13 and broken by a sudden blow or blows applied at the center of the weld. The blow should preferably be applied by a power hammer or falling weight, and be of sufficient intensity to cause a sharp, sudden fracture of the specimen through the nicked portion.

Bend-Test Specimen. The dimensions of the specimen shall be in accordance with Fig. U-14. The length may vary with the thickness of the piece and is unimportant, provided it is long enough to permit the bending operation. The bend in the specimen may be started by holding the specimen in a vise about one-third from the end, producing an initial bend at this point with hammer blows. Another bend about one-third from the other end may be produced in the same manner.

The specimen with the initial bend at each end is then placed as a strut in a vise or compression machine and pressure applied gradually (that is, without shock) at the ends until failure occurs in the outside fibers of the bend specimen. When a crack is observed in the convex surface of the specimen between the edges, the specimen shall be considered to have failed and the test shall be stopped. Cracks at the corners of the specimen shall not be considered as a failure. The appearance of small defects in the convex surface shall not be considered as a failure if the greatest dimension does not exceed $^1/_{16}$ in.

The performance of the specimen is evaluated by measurement of the outside-fiber elongation. This measurement may be made by means of a flexible scale. The elongation shall be recorded in per cent.

(*d*) *Test Results.* The minimum requirements for the test results are as follows:

Tension Tests. Each full-section tension specimen should fail in the plate if the weld reinforcement is retained, but if failure occurs in the weld metal or along the line of fusion between the weld metal and the plate, then the tensile strength shall not be less than the minimum of the specified tensile range of the plate used. For the reduced-section tension-test specimens the tensile strength shall not be less than 95 per cent of the minimum of the specified tensile range of the plate used.

Bend Test. The ductility requirement by the free-bend-test method shall be at least 20 per cent for electric-arc welding and at least 15 per cent for oxy-acetylene welding.

Nick-Break Test. The nick-break test for soundness of the weld shall show in the fractured surface complete penetration through the entire thickness of the weld, absence of oxide or slag inclusions, and a degree of porosity not to exceed six gas pockets per square inch of the total area of the weld surface exposed in the fracture, the maximum dimension of any such pocket not to be in excess of $^1/_{16}$ in.

X-ray tests of the test plates as provided for in Par. U-68*i* may be substituted for the nick-break test.

U-70. *Class 3.* All vessels covered by this Code, not exceeding $^5/_8$ in. plate thickness and used for the storage of gases or liquids at temperatures not materially exceeding their boiling temperature at atmospheric pressure, and at pressures not to exceed 200 lb. per sq. in., and/or not to exceed a temperature of 250° F., may be included in this class, excepting those containing lethal gases or liquids. The maximum allowable working pressure of the vessel shall be calculated on the basis of a maximum unit joint working stress ($S \times E$) as follows:

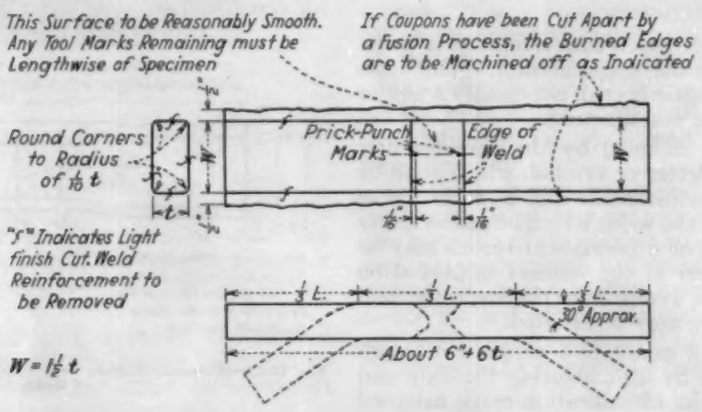

This Surface to be Reasonably Smooth. Any Tool Marks Remaining must be Lengthwise of Specimen
If Coupons have been Cut Apart by a Fusion Process, the Burned Edges are to be Machined off as Indicated
Round Corners to Radius of 1/10 t
Prick-Punch Marks
Edge of Weld
"f" Indicates Light finish Cut. Weld Reinforcement to be Removed
W = 1½ t
30° Approx.
About 6" + 6t

Fig. U-14—Specimen for Free-Bend Test

Double-welded butt joints for all joints.....	8000 lb.
Single-welded butt joints for girth or head joints	6500 lb.
Double full-fillet lap welds for girth joints only	7000 lb.
Plug or intermittent welds for girth or head joints	5600 lb.

For single-welded butt joints for longitudinal joints and for material of thickness of less than $^1/_4$ in., the maximum unit joint working stress ($S \times E$) shall not exceed 5600 lb. per sq. in.

Welding for this class shall meet the following test requirements:

(*a*) Each manufacturer shall be responsible for the quality of the welding done by his organization and shall conduct tests of the welders to determine their ability to produce welds which will meet the required tests. An authorized inspector shall have the right at any time to call for and witness the making of test specimens by any welder and to observe the physical tests.

The tests of a welder shall be effective for a period of six months only, at the end of which time a repetition of the tests shall be made by the manufacturer. The tests conducted by one manufacturer shall not qualify a welder to do work for any other manufacturer.

Each welder shall be assigned by the manufacturer an identifying number, letter, or symbol, which shall be stamped on all vessels adjacent to and at intervals of not more than 3 ft. along the welds which he makes either by

hand or by machine, or a permanent record may be kept by the manufacturer of the welders employed on each joint, which shall be available to the inspector, and in such case the stamping may be omitted.

The manufacturer shall maintain a permanent record of the welders employed by him, showing the date and result of the tests and the identification mark assigned to each. These records shall be certified to by the manufacturer and accessible to the inspector. (A sample data report sheet appears on page 18.)

(*b*) *Test Plates.* Material for test plates shall conform to the specifications for the material to be used in constructing the unfired pressure vessel. The tests for welders shall be considered as applying only to such materials.

Two test plates shall be made; one of a thickness of $^1/_4$ in., and the other of a thickness of $^5/_8$ in., and all specimens of each plate shall be tested.

Where the maximum thickness employed in construction under these Rules is less than the limit permitted in these test requirements, test plates of the maximum thickness for which approval is desired, may be substituted for the $^5/_8$ in. test plate.

The required dimensions for the test plates and specimen location shall be as given in Fig. U-10, except that the nick-break-test specimens are not required.

Type of Joint. For these test requirements, the type of joint shall be the single-welded butt joint for the $^1/_4$ in. test plate and the double-welded butt joint for test plates having a thickness greater than $^1/_4$ in. The preparation of the edges of the test plate for welding shall be the same as to be employed in construction.

Procedure of Welding. The test plates shall be welded under the same procedure as to be employed for construction. The process of welding, size and type of welding rod, number of welding layers, position in which the welding is done, etc., shall be the equivalent of that to be used for construction. Only such accessories to or supplements of the welding procedure, for example the employment of weld backing-up strips, shall be employed in the production of the test plates as will be required for construction.

The external appearance of the welds and the amount of weld reinforcement shall conform to the requirements for construction, and the maximum reinforcement for the test plates shall not exceed the minimum required for construction.

(*c*) *Test Specimens.* Two full-section tension-test specimens, two reduced-section tension-test specimens and two bend-test specimens shall be required from each test plate.

Full-Section Tension-Test Specimen. The shape and dimensions of the tension-test specimen shall be as shown in Fig. U-11, with the weld at the center. Data shall be recorded on the ultimate strength and computed from the area of the base-metal section (pounds per square inch).

Reduced-Section Tension-Test Specimen. The shape and dimensions of the test specimen shall be as shown in Fig. U-12. The top and bottom sides of this specimen should be machined to "clean up" the surfaces. The data to be recorded in connection with the reduced-section tension-test specimens shall be the same as for the full-section tension-test specimens.

Bend-Test Specimen. The dimensions of the specimen shall be in accordance with Fig. U-14. The length may vary with the thickness of the piece and is unimportant, provided it is long enough to permit the bending operation. The bend in the specimen may be started by holding the specimen in a vise about one-third from the end, producing an initial bend at this point with hammer blows. Another bend about one-third from the other end may be produced in the same manner.

The specimen with the initial bend at each end is then placed as a strut in a vise or compression machine and pressure applied gradually (that is, without shock) at the ends until failure occurs in the outside fibers of the bend specimen. When a crack is observed in the convex surface of the specimen between the edges, the specimen shall be considered to have failed and the test shall be stopped. Cracks at the corners of the specimen shall not be considered as a failure. The appearance of small defects in the convex surface shall not be considered as a failure if the greatest dimension does not exceed $^1/_{16}$ in.

The performance of the specimen is evaluated by measurement of the outside-fiber elongation. This measurement may be made by means of a flexible scale. The elongation shall be recorded in per cent.

(*d*) *Test Results.* The minimum requirements for the test results are as follows:

Tension Tests. Each full-section tension specimen should fail in the plate if the weld reinforcement is retained, but if failure occurs in the weld metal or along the line of fusion between the weld metal and the plate, then the tensile strength shall not be less than 90 per cent of the minimum of the specified tensile range of the plate used. For the reduced-section tension-test specimen the tensile strength shall not be less than 85 per cent of the minimum of the specified tensile range of the plate used. In no case shall the tensile strength be less than 42,000 lb. per sq. in.

Bend Test. The ductility requirement by the free-bend-test method shall not be less than 10 per cent.

U-71. *Material.* (a) The materials used in the fabrication of any fusion-welded pressure vessel covered by this Code shall conform to Specifications S-1 for Steel Boiler Plate, S-2 for Steel Plates of Flange Quality for Forge Welding or S-4 for Seamless Steel Drum Forgings, of Section II of the Code (1930 Edition). Shells fabricated from pipe shall conform to Specification S-18 for Welded and Seamless Steel Pipe. The carbon content in all such material shall not exceed 0.35 per cent.

(b) Material for manhole frames, nozzles and other pressure connections which are to be joined to the shell or heads by fusion welding shall, when forged or rolled, comply with the specifications given for shell plate and heads as to chemical and physical properties, and be of good weldable quality. Steel castings and commercial nozzles may be used only when the material has been proved to be of good weldable quality.

(c) If, in the development of the art of welding, other materials than those herein described become available, specifications may be submitted for consideration.

U-72. *Preparation for Welding.* The plates or sheets to be joined shall be accurately cut to size and formed. In all cases the forming shall be done by pressure and not by blows, including the edges of the plates forming longitudinal joints of cylindrical vessels.

Particular care should be taken in the layout of joints in which fillet welds are to be used so as to make possible the fusion of the weld metal at the bottom of the fillet. Great care must also be exercised in the deposition of the weld metal so as to secure satisfactory penetration.

If the thickness of the flange of a head to be attached to a cylindrical shell by a butt joint exceeds the shell thickness by more than 25 per cent (maximum $^1/_4$ in.), the flange thickness shall be reduced at the abutting edges as shown in Fig. U-15.

The edges of the plates at the joints shall not have an offset from each other at any point in excess of one-

quarter of the thickness of the plate, except for plates in excess of $^3/_4$ in. in thickness, in which the offset shall not be more than 10 per cent (maximum $^1/_8$ in.) for longitudinal joints, or 25 per cent (maximum $^1/_4$ in.) for girth joints.

In all cases where plates of unequal thicknesses are abutted, the edge of the thicker plate shall be reduced in some manner so that it is approximately the same thickness as the other plate.

The design of welded vessels shall be such that bending stresses are not brought directly upon the welded joint. Corner welds shall be avoided unless the plates forming the corner are properly supported independently of such welds.

Bars, jacks, clamps or other appropriate tools may be used to hold the edges to be welded in line The edges of butt joints shall be so held that they will not overlap during welding. Where fillet welds are used, the lapped plates shall fit closely and be kept together during welding.

Particular attention is called, however, to the importance of the provision that there shall be no valley or groove along the edge of or in the center of the weld, but that the deposited metal must be fused smoothly and uniformly into the plate surface at the top of the joint.[1] The finish of the welded joint shall be reasonably smooth and free from irregularities, grooves or depressions. The reinforcement for a single-welded butt joint shall be not less than $^1/_{16}$ in. The reinforcement may be machined off, if so desired.

The longitudinal joints of Class 3 vessels may be of the double-welded butt type for thicknesses of $^5/_8$ in. or less, or of the double-welded lap type for thicknesses of $^3/_8$ in. or less, or of the single-welded butt type for thicknesses of $^1/_4$ in. or less. If of the lap type the throat dimension of each of the welds shall not be less than $^5/_8T$, where T represents the thickness of the plate. Both edges of the lap shall be welded and the surface overlap shall not be less than $4T$.

(*b*) Where vessels are made up of two or more courses

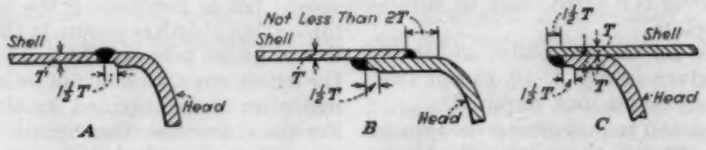


Fig. U-15—Welded Head Attachments

The surfaces of the sheets or plates to be welded shall be cleaned thoroughly of all scale, rust, oil or grease for a distance of not less than $^1/_2$ in. from the welding edge. Grease or oil may be removed with gasoline, lye or the equivalent. A steel-wire scratch brush may be used for removing light rust or scale, but for heavy scale, slag and the like a grinder, chisel, air hammer or other suitable tool shall be used to obtain clean and bright metal. When it is necessary to deposit metal over a previously welded surface, any scale or slag therefrom shall be removed by a roughing tool, a chisel, an air chipping hammer or other suitable means to prevent inclusion of impurities in the weld metal.

The dimensions and shape of the edges to be joined shall be such as to allow thorough fusion and complete penetration.

For double-welded butt joints the reversed sides shall be chipped, ground or melted out, so as to secure a clean surface of the originally deposited weld metal, prior to the application of the first bead of welding on the second side. Such chipping, grinding or melting out shall be done in a manner that will insure proper fusion of the weld metal.

If the welding is stopped for any reason, extra care shall be taken in restarting to get full penetration to the bottom of the joint and thorough fusion between the weld metal and the plates, and to the weld metal previously deposited.

Where single-welded butt joints are used, particular care shall be taken in aligning and separating the edges to be joined so that complete penetration and fusion at the bottom of the joint will be assured.

U-73. *Joints.* (*a*) *Longitudinal.* Longitudinal joints on Classes 1 and 2 vessels shall be of the double-welded butt type and shall be reinforced at the center of the weld on each side of the plate by at least $^1/_{16}$ in. up to and including $^5/_8$ in. plate, and up to $^1/_8$ in. for heavier plates. The reinforcement may be removed, but if not removed shall be built up uniformly from the surface of the plate to a maximum at the center of the weld. with welded longitudinal joints, the joints of adjacent courses shall be not less than 60° apart.

(*c*) *Circumferential.* Circumferential joints on Class 1 vessels shall be of the double-welded butt type. Circumferential joints on Class 2 vessels shall be of the double-welded butt type except for thicknesses of $^5/_8$ in. or less, in which case they may be of the single-welded butt type. Circumferential joints on Class 3 vessels may be of the butt or lap type. The details of all these joints shall conform to the requirements for longitudinal joints, as given in (*a*).

(*d*) Dished heads concave to the pressure when used on Class 3 vessels may be inserted with a driving fit and fillet welded inside and outside, except that for vessels 20 in. in diameter or less the heads may be welded on the outside only. The welds shall be located on the flange of the head at a distance not less than twice the thickness of the head from the point of tangency of the knuckle.

(*e*) Heads concave to the pressure and/or plate edges at girth joints to be attached by butt joints shall be aligned so that the deviations are not more than permitted by the limitations of Par. U-72, but if greater, correction shall be made by reforming the shell or head, whichever is out of true, until the errors are within the limits specified. The edges of head and girth joints shall be kept separated at the point of welding enough to insure thorough penetration of the weld metal.

(*f*) *Holes.* No unreinforced hole shall be located in a welded joint. When an unreinforced hole in the plate is located near a welded joint, the minimum distance between the edge of a hole and the edge of the weld shall be equal to the thickness of the plate when the plate thickness is from 1 in. to 2 in. With plates less than 1 in. thick, this minimum distance shall be 1 in. With plates over 2 in. in thickness, the minimum distance shall be 2 in.

[1] If the reinforcement is built up so as to form a ridge with a valley or depression at the edge of the weld next to the plate, the result is a notch which causes concentration of stress and reduces the strength of the joint.

U-74. *Dished Heads.* Dished heads convex to the pressure shall have a flange not less than $1^1/_2$ in. long and shall be inserted into the shell with a driving fit and welded as shown in Fig. U-15.

Dished heads concave to the pressure shall have a length of flange not less than 1 in. for shells not over 24 in. in diameter. For vessels over 24 in. in diameter this length shall be not less than $1^1/_2$ in.

U-75. *Inlet and Outlet Connections.* Pipe connections may be made as provided for in Par. U-59.

Nozzles may be fusion-welded, with or without reinforcement, to the shell or to the spherical portions of the head (see Fig. U-16). When the inside diameter of the vessel is 36 in. or greater, the inside diameter of an unreinforced fusion-welded nozzle shall not exceed that given in the following equation:

$$d = 0.1155\frac{D}{K}\sqrt{6K-5K^2-1}$$

where

d = maximum allowable inside diameter of nozzle, in in.
D = inside diameter of shell, in in.
K = ratio of computed stress in the solid plate to one-fifth of the ultimate tensile strength stamped on the plate, $=\frac{PR}{ST}$

If K is less than 0.333, the maximum allowable value of d shall be 0.231 D.

Nozzles of the type shown in Fig. U-16K shall have reinforcing rings designed in accordance with the rules for manholes given in Pars. U-55, U-56 and U-57. For other reinforced nozzles, the thickness of the reinforcing pad shall not be less than that given in the following equation:

$$t = T\left[3.75\frac{d}{D} - 0.525\frac{(1-K)}{K}\right]$$

where

t = required thickness of pad, in in.
T = thickness of shell or head, in in.
d = inside diameter of nozzle, in in.
D = inside diameter of shell, in in.
K = ratio of computed stress in the solid plate to one-fifth of the ultimate tensile strength stamped on the plate, $=\frac{PR}{ST}$

The thickness of the reinforcing pad shall not be less than $^3/_4$ in. when the thickness of shell or head to which the same is fitted is 2 in. or less; when thickness of head or shell is greater than 2 in., the minimum thickness of the pad shall be 1 in. The width of the pad along the longitudinal axis of the shell or any axis of a head, shall not be less than the inside radius of the nozzle less the nozzle thickness.

Nozzles which are attached by fusion welding to vessels whose seams are of riveted construction shall be attached prior to the making up or attachment of the courses by riveting, or, if they do not require stress relieving, shall have such nozzles located at a distance from the riveted seam equal to the diameter of the nozzle plus 4 times the shell plate thickness.

U-76. *Stress Relieving.* All Class 1 fusion-welded vessels shall be stress relieved.

Class 2 fusion-welded vessels shall be stress relieved where both the wall thickness is greater than 0.58 in. and the shell diameter less than 20 in., and for other wall thicknesses and shell diameters, where the ratio of the diameter to the cube of the shell thickness is less than 100.

Where stress relieving is required, it shall be done by

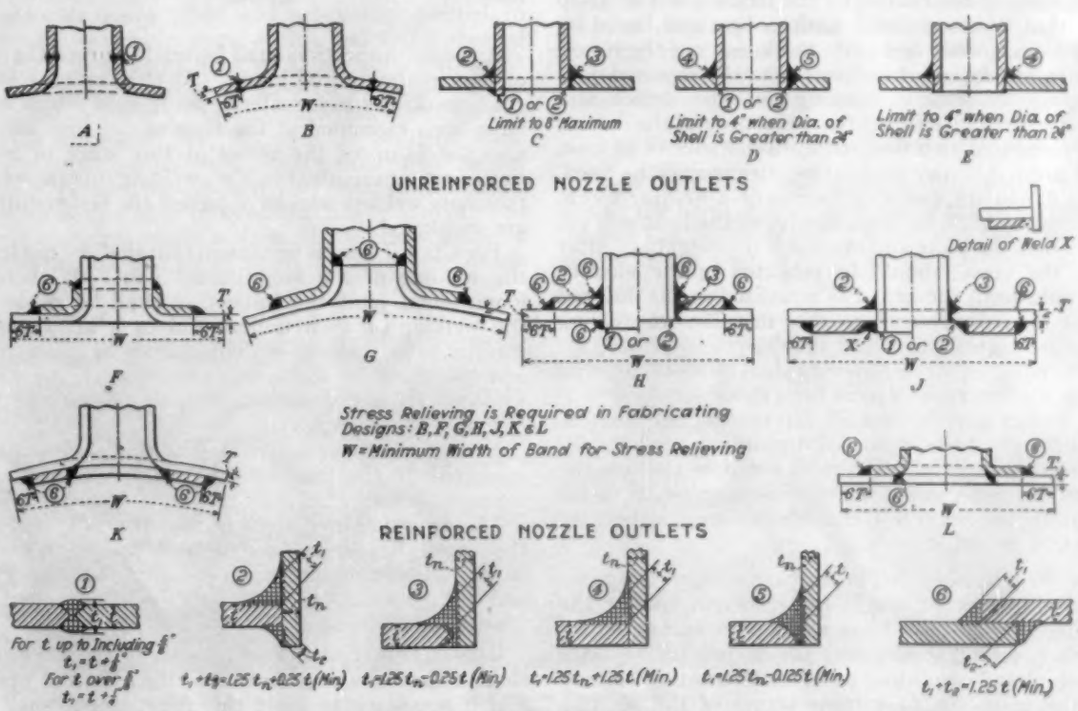

A
B
Limit to 8" Maximum
C
Limit to 4" when Dia. of Shell is Greater than 24"
D
Limit to 4" when Dia. of Shell is Greater than 24"
E
UNREINFORCED NOZZLE OUTLETS
Detail of Weld X
F
G
H
J
Stress Relieving is Required in Fabricating Designs: B, F, G, H, J, K & L
W = Minimum Width of Band for Stress Relieving
K
L
REINFORCED NOZZLE OUTLETS
For t up to Including 5/8"
For t over 5/8"
t1 + t2 = 1.25 tn + 0.25 t (Min.)
t1 + 1.25 tn - 0.25 t (Min.)
t1 + 1.25 tn + 1.25 t (Min.)
t1 + 1.25 tn - 0.125 t (Min.)
t1 + t2 = 1.25 t (Min.)

Fig. U-16—Types of Fusion-Welded Nozzle Construction

heating uniformly to at least 1100° F., and up to 1200° F., or higher, if this can be done without distortion. The structure or parts of the structure shall be brought slowly up to the specified temperature and held at that temperature for a period of at least one hour per inch of thickness, and shall be allowed to cool slowly in a still atmosphere.

Nozzles attached by welding shall be stress relieved on all vessels requiring stress relief and in all cases specified in Fig. U-16.

The structure shall be stress relieved by any of the following methods:

(a) Heating the complete vessel as a unit.

(b) Heating a complete section of the vessel (head or course) containing the part or parts to be stress relieved before attachment to other sections of the vessel.

(c) In cases where the vessel is stress relieved in sections, stress relieving the final girth joints by heating uniformly a circumferential band having a minimum width of 6 times the plate thickness on each side of the welded seam in such a manner that the entire band shall be brought up to the temperature and held for the time specified above for stress relieving.

U-77. *Hydrostatic and Hammer Tests.* (a) All fusion-welded pressure vessels shall be subjected to the hydrostatic pressure as prescribed in Par. U-64, and while subject to this pressure shall be given a thorough hammer or impact test. This impact test shall consist of striking the plate at 6-in. intervals on both sides of the welded joint and for the full length of all welded joints. The weight of the hammer in pounds shall approximately equal the thickness of the shell in tenths of an inch, but not to exceed 10 lb., and the plate shall be struck with a sharp swinging blow. The edges of the hammer shall be rounded so as to prevent defacing the plates.

Following this test, the pressure shall be raised to not less than twice the maximum allowable working pressure and held there for a sufficient length of time to enable an inspection to be made of all joints and connections.

The maximum allowable working pressure for the hydrostatic tests as determined by the formula in Par. U-20 shall be that at atmospheric temperature and based on the actual dimensions and plate thicknesses of the vessel.

Pinholes, cracks or other defects shall be repaired only by chipping, machine or burning out the defect and rewelding. For gas welding the metal around the defects shall be preheated to a dull red for a distance of at least 4 in. all around. Any preheating means may be used, such as a flange fire, gas or oil burner or a welding torch. The preheating shall be done slowly, so the heat will get well back into the plate and expand it thoroughly. After welding, the vessel should be reheated in the vicinity of such weld until the heat has equalized in the dull red spot, and then slowly cooled. For metallic arc welding preheating or reheating is not required.

Vessels requiring stress relieving shall be stress relieved after any welding repairs have been made.

After repairs have been made the vessel shall again be tested in the regular way, and if it passes the test the inspector shall accept it. If it does not pass the test the inspector can order supplementary repairs, or, if in his judgment the vessel is not suitable for service, he may permanently reject it.

U-78. *Inspection.* The inspector may designate stages of the work at which he wishes to inspect the welded joints of a Class 1 vessel, and the manufacturer shall either submit the vessel for inspection in such partly completed condition, or as an alternative he may permit the inspector to witness stages of the welding operation at such times as the inspector may select.

For Class 2 vessels the first inspection shall be made during the welding of the longitudinal joint. At this time the inspector shall inspect the plate material and the fit-up of the work, and observe the workmen to see that only welders who have passed the test requirements are employed on the work of welding.

MANUFACTURERS' DATA REPORT FOR CLASSES 2 AND 3 TEST REQUIREMENTS

Manufacturer.....

Location.....Date of Test.....

Welder.....Symbol.....Number.....

Welding for Class.....Welding Process or Trade Name.....

1. Test Plate Number	
2. Type of Preparation for Joint	
3. Thickness of Material	
4. Class of Material	
5. Position of Welding	
6. Size of Electrode or Welding Rod	
7. Type of Electrode or Welding Rod	
8. Number of Beads or Layers	
9. Reinforcement	
10. Appearance of Weld	
Full-Section Tension Test	
(a) Lb. per sq. in.	
(b) Lb. per sq. in.	
Reduced-Section Tension Test	
(a) Lb. per sq. in.	
(b) Lb. per sq. in.	
Nick-Break Test	
(a) Appearance	
(b) Appearance	
Free-Bend Test	
(a) Per cent	
(b) Per cent	

The undersigned manufacturer certifies that the statements made in this report are correct and that the test plates were prepared, welded and tested in accordance with the requirements of the A. S. M. E. Code for Unfired Pressure Vessels.

Date.....19.... Signed.....

(Manufacturer)

A second inspection shall be made during the welding of the circumferential joints. At this time the inspector shall check any new material being used which may not have been examined at the time of the first inspection, also the fit-up of the vessel at this stage of construction, and again observe the welding operators to see that only welders who have passed the test requirements are employed.

For Class 3 vessels one inspection shall be made during the welding of the longitudinal joint. If there is no longitudinal joint the inspection shall be made during the welding of a circumferential or a head joint. At this time the inspector shall check the plate material and the fit-up of the work, and observe the workmen to see that only welders who have passed the test requirements are employed.

Every pressure vessel covered by this Code shall also be inspected at the time of the hydrostatic-pressure and hammer tests.

The manufacturer shall certify that the welding on the vessel has been done only by welders who have passed the test requirements and that the same material and technique used in making the tests were employed in fabricating the vessel.

U-79. *Distortion.* The cylinder or barrel of a vessel shall be circular at any section within a limit of 1 per cent, and if necessary to meet this requirement shall be reheated, rerolled or reformed.

Some Methods and Effects of Machine Gas Cutting

By L. M. CURTISS

†Paper read before the 32nd annual convention of International Acetylene Association, Chicago, November 13, 1931, by L. M. Curtiss, Superintendent, 140-inch and 206-inch Rolling Mills, Lukens Steel Company, Coatesville, Pennsylvania.

This article deals with methods of machine gas cutting heavy plate and the metallurgical effect upon the metal after it is cut, and further considers certain economies which may be realized.

The practices and results described in this article apply only to machine gas cutting.

Machine gas cutting made its first appearance in England about 1906, and while it was fairly successful at that time its commercial growth was very slow. The trouble encountered in the early stages of its development was due to the machine's lack of range, inflexibility and its inability to give good quality cutting in gages of plate where the demand would be the greatest. The torch problem, which required years for its solution, was not simply a matter of pressures and tip sizes, but also of design, because all passages must be of the proper size and proportion with outlet orifices perfect in mechanical workmansip so that the gases would have an unhampered flow.

It is extremely difficult to picture the tremendous opportunities which this art has offered. Previous to the use of oxygen, heavy plate was practically limited to a two-inch thickness in gage, which had to be sheared mechanically in straight lines with the usual out-of-flat condition characteristic of all sheared material. Compare with this a twenty to thirty inch cut, which can be made with oxygen today, not only in straight lines, but also in a curved or irregular direction, with the cut edge either vertical or beveled and without the usual shear distortion. This progress in heavy cutting has created in the steel world a demand for heavy material to be used as machine parts, or in high pressure vessels where elevated temperatures must be withstood. Today there are thousands of uses for gas cut heavy steel plate which can be met in a few hours with the aid of simple templates, in place of complicated patterns, thus avoiding days of preparation and insuring reliable shapes cut from rolled steel.

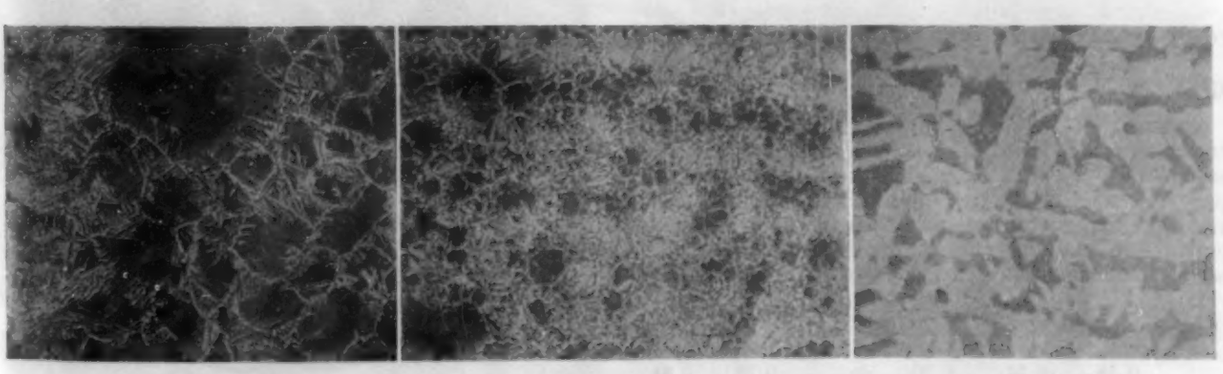
Wage Payment

During the development of gas cutting, the first thought was to "make the cut," especially on extreme thickness, and, secondly, to give the edges a good, smooth, pleasing appearance. These two things required years of study, for it was necessary to determine the proper machine speed, the correct pressure and volume of oxygen and the proper tip size for each and every gage cut.

Little thought was given to the actual cost of the operation as the advantage to be derived was so great that it overshadowed the expense of cutting. The cutters were generally paid a straight hourly rate, and were given general instructions by the Foreman on how the job should be done. An incentive wage payment plan was considered very illogical as a large plate could easily be spoiled by hurried work, and because the labor involved in cutting was not the initial consideration. The cost of oxygen and acetylene consumed in cutting heavy thicknesses is several times the cost of the labor involved. There was the danger that an operator in accomplishing his task in the least possible time would use excessive oxygen, thus more than counteracting any benefit derived from fast work. Lukens Steel Company tackled this problem with many misgivings and were many times advised that it could not be solved. After much study, however, a payment plan was devised whereby each man was paid for the exact amount of work accomplished, and, in addition, a bonus was paid on the amount of oxygen saved below a set standard; a penalty was also applied for poor workmanship. It is gratifying to say this plan was successful from the beginning, and each succeeding month showed an improvement in labor efficiency. The oxygen consumption instead of climbing, as feared, took a downward course, resulting in a remarkable saving. The quality of cutting was in no way impaired and the amount of rejected material, due to carelessness, was materially reduced.

Effect of Cutting

There has been considerable discussion, especially among the users of steel plate, as to the effect of gas cutting on the material cut. When observed microscopically, the cut edge is found to be materially altered as



Extreme Gas Cut Edge (Sorbitic Structure) | Transition State between Sorbite and Pearlite | Unaltered Pearlitic Structure of Original Plate

Fig. 1—Photomicrograph of Gas Cut Edge from a 6" Plate

compared with the original metal. Apparently this is a physical change, as the pearlitic steel has been transformed into an unstable condition, taking one of three forms: sorbitic, troostitic or martensitic, according to the amount of carbon present in the steel and the speed with which the metal is cooled. This physical change is due to the metal adjacent to the cut being heated considerably above its critical range and cooling quickly through this range. The drop in temperature is caused by heat conductivity of the cold surrounding metal, by radiation losses, and by the fact that the heat is applied only momentarily at any one point, the machine being in constant motion while cutting. Another interesting change is the tremendous grain growth which occurs on the gas cut edge; the grain size gradually tapering back to the normal size in the original metal. Ordinarily, grain growth is caused by holding a piece of steel at an elevated temperature for a prolonged period of time; both temperature and time being functions of its progress. The development of the grains in this case is due principally to the intensity of the heat, as the time element is very short.

The change in this altered area has previously been considered as merely a physical without any chemical alteration, but it has now been discovered that the carbon content is increased on the burned edges. When the specimen is annealed, however, this carbon difference is equalized. Carbon analyses were made from layers $^1/_{32}$ of an inch thick, planed from the gas cut edges of various plates. Analysis No. 1 represents the outside layer, No. 2 the second layer, etc.

Table Showing Carbon Analyses of Burned Edges

(Before Annealing)

No.	Plate A	Plate B	Plate C	Plate D
1	0.32	0.27	0.16	0.12
2	0.17	0.27	0.12	0.12
3	0.17	0.23	0.09	0.11
4	0.10	0.22	0.10	0.10

(After Annealing)

No.	Plate A	Plate B	Plate C	Plate D
1	0.19	0.21	0.08	0.10
2	0.19	0.23	0.08	0.11
3	0.18	0.22	0.10	0.10
4	0.17	0.23	0.11	0.10

The next step was to try and find the cause of this carbon increase, the three possibilities being:

1. Absorption of carbon from acetylene.
2. Pearlite and sorbite might give different carbon results under the same method of analysis.
3. An actual local change due to the physical alteration.

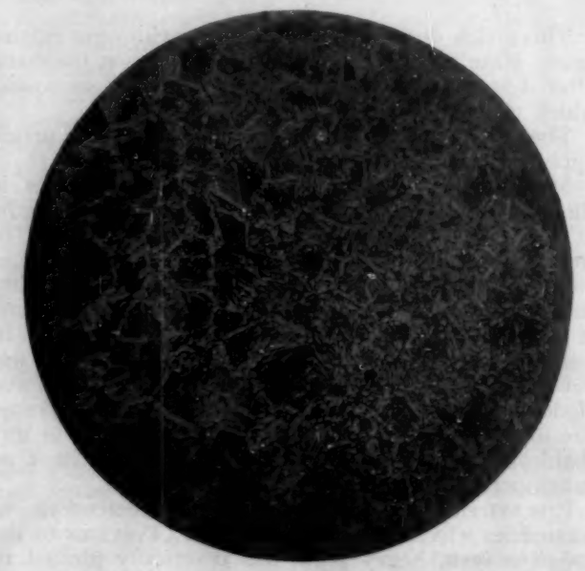
Carbon analyses were taken from several samples, some of which were cut with acetylene, and some of which were cut with hydrogen, the idea being to compare the effect of the two fuels and to eliminate, if possible, the thought of any carbon absorption by the acetylene. The shavings were taken as previously described, each one representing $^1/_{32}$ of an inch in thickness.

	Plate E		Plate G		Plate J	
No.	Acetylene	Hydrogen	A	H	A	H
1	0.18	0.21	0.20	0.22	0.28	0.31
2	0.18	0.19	0.16	0.18	0.26	0.26
3	0.17	0.16	0.16	0.15	0.24	0.24
4	0.17	0.16	0.15	0.15	0.24	0.23

The results indicate that any increase in carbon on the outside cut edge cannot be attributed to the carbon in the acetylene as the hydrogen may also give similar results.

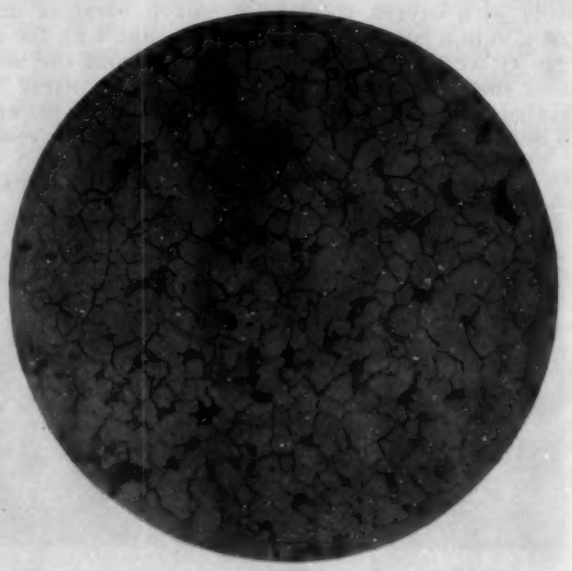
The No. 1 shavings were annealed in order to re-establish the pearlitic condition, and were then analyzed for carbon. These checked identically with the original No. 1 samples. This, of course, eliminated the possibility of obtaining a difference in carbon from sorbite and pearlite under the same method of analysis.

The one remaining explanation for the increase in carbon of the outside gas cut edge is that the pearlitic patches in the original steel have been absorbed while passing through the transformation range, forming what is known as austenite, or a solid solution. When the cooling action starts, the ferrite is thrown out of the solid solution first, thereby making the remaining solution



Gas Cut Edge
(Sorbitic Structure)

Fig. 2



Same Gas Cut Edge after Annealing
(Pearlitic Structure)

Fig. 3

higher in carbon. In view of the fact that the hottest part of the metal is next to the kerf, the carbon migrates toward this hotter zone, where it is finally concentrated. Sorbite is formed because the metal is cooled so quickly that the pearlite does not have a chance to re-establish itself. This is checked by the fact that whenever a gas cut piece is normalized or annealed the area of increased carbon and altered physical structure disappears completely and the steel returns to its original state.

These physical and chemical changes in the steel leave a thin hardened zone on the outside edge, the penetration of which is usually very superficial. With ordinary steels of 0.30 carbon and under, no particular difficulty is experienced in bending or fabricating as the sorbitic hardening is not very intense. With high carbon and alloy steels, the precautions of annealing or machining should be used to remove the hardened edge. There are some exceptions, however, in the low carbon steels, which should be recognized: where a bend occurs with the gas cut edge on the outside surface; or in a machine part where stresses are concentrated at one point and the member is subjected to the fatigue of intermittent tensile stresses. In cases of this kind, all traces of gas cutting should be removed by annealing, planing or grinding. It is extremely necessary to remove any nicks or notches, as they are particularly susceptible to the effect of intermittent stresses, and form an excellent opportunity for the development of incipient cracks, which in turn may develop into a large fracture.

The accompanying photo-elastic photographs give an optical picture of concentrated stresses on a celluloid model of a housing plate under stress.

Figure 4 shows a dark line with two projections pointing toward the in-cut of the housing plate, and also a smooth, semi-circular, lighter line immediately adjacent to the in-cut, which show the effect of stresses and their concentration at the two projecting points.

Figure 5 shows the same housing plate, except that the in-cut has been slightly nicked. The dark line is again apparent with the lower projection more sharply defined, and in addition the lighter line, instead of being a smooth curve, is broken and shows a projection pointing directly toward the nick. This indicates that the nick has the effect of concentrating stresses.

The depth of penetration of the altered zone has been found to have a definite relation to the thickness of the material cut. This relationship is shown graphically in Fig. 6.

Preheating the Steel

If the simple precaution is taken of preheating the steel before gas cutting, the cooling effect will be retarded and this will prevent, to some extent, the formation of sorbite and reduce the hardness. High carbon and alloy steels, such as chrome-vanadium, which are particularly susceptible to temperature changes, should always be preheated, and should be annealed immediately after cutting to re-establish the pearlitic condition and to remove all cooling strains.

Fig. 4
Housing Plate
Smooth In-cut

Fig. 5
Same Housing Plate
with Nicked In-cut

Photo-Elastic Study

Hot cutting is not only beneficial to the steel, but is also economical in the use of oxygen. Any steel is more easily oxidized at elevated temperatures than at atmospheric temperature. Special care must be exercised, however, on particularly thick sections, where the in-

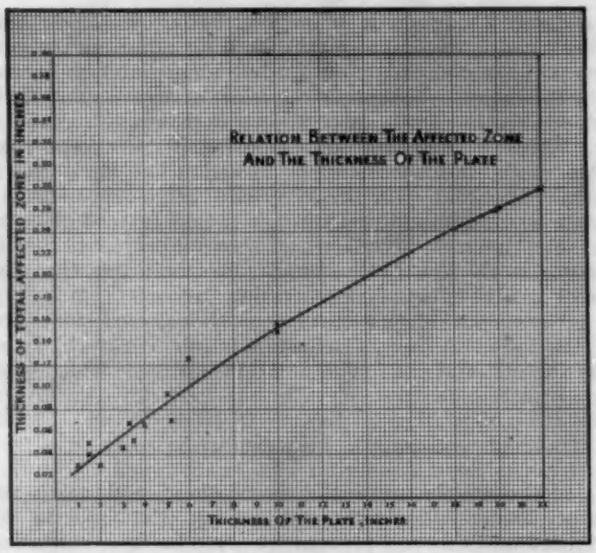

Relation Between The Affected Zone
And The Thickness Of The Plate
Thickness Of Total Affected Zone In Inches
Thickness Of The Plate, Inches

Fig. 6

terior is considerably hotter than the exterior. The oxygen may start its penetration without much difficulty, but upon entering the interior of the section may fail to go through and will cause a flare-up in the cutting. This stoppage is caused by the hot center, which oxidizes so readily that a cavity is formed on the inside of the piece and the flame once being diverted is not easily adjusted. The operator at this point usually makes the wrong move by increasing the pressure, which intensifies the trouble and increases the size of the cavity to such an extent that the slab may be ruined. There are some differences of opinion as to the proper temperature of the steel for the most efficient use of oxygen to obtain the correct penetration, and to leave the steel in the best shape metallurgically. For all practical purposes 500 to 600° F. should give the best combined result.

Quite a problem is presented in making clean, economical cuts in steel slabs between twenty and thirty inches thick. A generous supply of fuel is needed to support the preheating flame. High oxygen pressure is required to penetrate the entire thickness, so that the molten oxide may be blown out of the kerf. If excess pressure is used, a large amount of oxygen passes straight through the cut without having any oxidizing action upon the metal and is consequently wasted. In order to compensate for this loss, the pressure may be reduced and the volume increased by the use of more than one regulator, and in some cases by using special equipment, such as a three hose torch with large openings and fitted with an extra large hose. Figure 7 shows a gas cut slab twenty-two inches thick, which presents a remarkably clean surface. Cuts of this thickness are not unusual and a 28″ gage has been cut with excellent results.

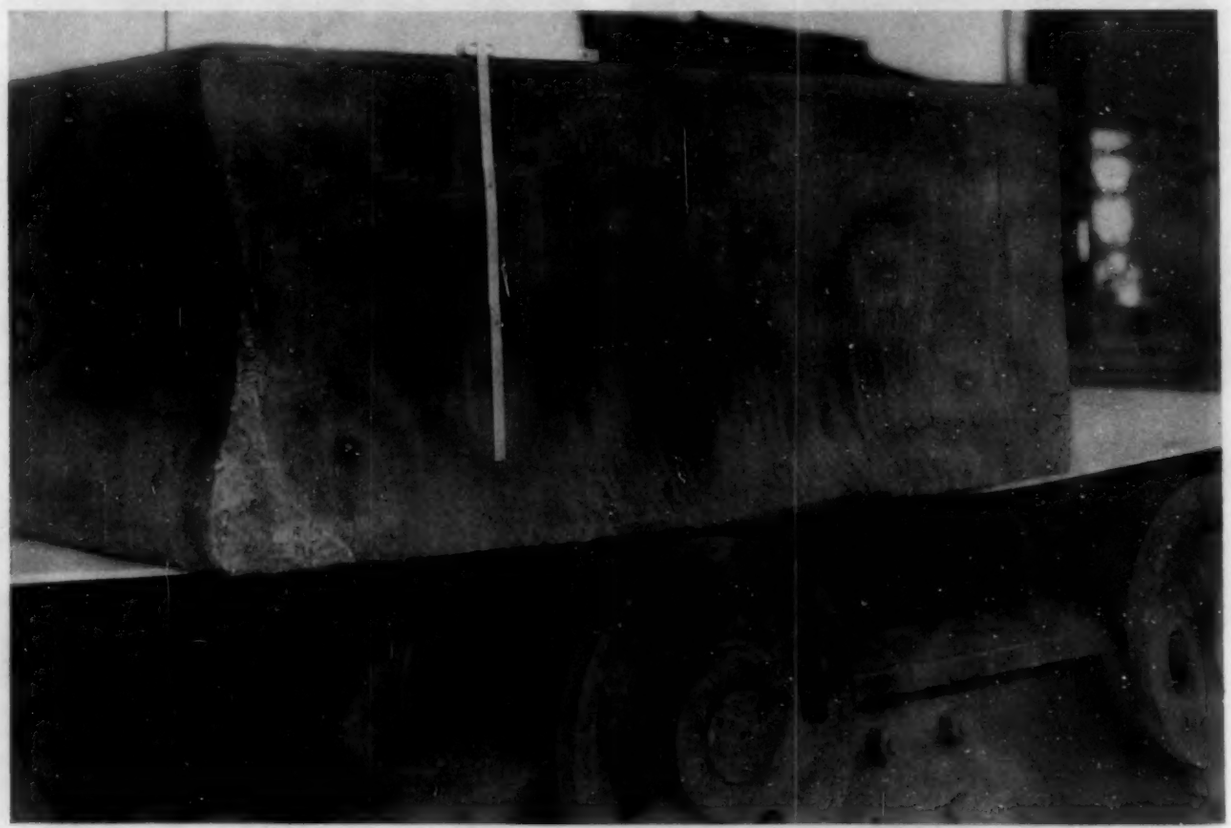


Fig. 7—Gas Cut through Steel Slab 22 Inches in Thickness

The Application of the Oxy-Acetylene Process in the Production of Motor Cars

By R. E. ESCH

†Paper presented before the 32nd annual convention of the International Acetylene Association, Chicago, November 11-13, 1931, by Mr. Esch, Plant Engineer, Graham-Paige Motors Corp., Wayne, Michigan.

The oxy-acetylene process was probably the first method of welding to be employed in the manufacture of motor cars. It has been used ever since the beginning of the automobile industry, and the fact that it still occupies a position in this field, where manufacturing methods have undergone rapid and sweeping changes, is a tribute to its intrinsic worth and adaptability.

In common with many other metal working industries, automobile manufacturing turns to welding as a supplement to the work done by metal cutting machine tools, drop forging hammers, drawing presses and other forming tools. The tendency is, of course, to produce every part of a motor car in as few operations as possible, and with a minimum of handling between operations. This has led to the building of a large number of automatic and semi-automatic machine tools that turn out parts at a cost in keeping with present-day conditions. Sometimes, however, the very completeness of these machines makes their cost prohibitive, and then it is often found economical to use several less complex machines to produce sections of a part, which are afterward welded together to a whole. Then too, especially in the manufacture of automobile body panels, cases occur where the combined demands of fashion and ease of assembling have created shapes impossible to produce on a press. These are usually made in sections and welded together before being assembled to the body frame.

Welding also effects important savings in material, as, for instance, when the high grade alloy steel head of a poppet valve is welded to a valve stem of less costly steel.

There is also an increasing tendency to abandon bolted and riveted construction in favor of welding, especially in the assembling of bodies.

Not the least important use the motor car industry makes of welding is in the construction and maintenance of production machinery and other factory equipment.

Whether the oxy-acetylene process or some other welding method be used, depends of course on the conditions in each individual case.

Generally speaking it may be said that the prime requisites of welded joints as at present used in motor cars is mechanical strength and a degree of hardness approximately equal to that of the surrounding metal. The latter is important on surfaces that are finished by sanding preparatory to lacquering, enameling or electroplating. The least irregularity in the surface caused by uneven action of the abrasive will be very apparent in the highly polished final product.

Only in a few instances is welding employed for joints that must be leak-proof under pressure, except, of course, in construction and maintenance work.

A few examples will serve to illustrate.

Hose Nipple in Water Jacket Cover Plate

This cover plate is a stamping of approximately 16-gage steel. It serves as a distribution manifold for the cooling water coming from the pump, and it also permits access to the interior of the water jacket. A short piece of steel tubing is welded to it for a hose nipple. This weld must of course be leak-proof, and for this reason and because of the thinness of the metal the oxy-acetylene flame is usually preferred to the electric arc.

The Oil Distribution Manifold

This consists of a piece of copper tubing connected to the delivery side of the oil pump and running the whole length of the engine. At proper intervals branch lines of smaller copper tubing connect it with the various bearings in the motor. The manifold is assembled in a jig, which locates the branch lines in the same relative position they will occupy in the motor and opposite and extending into holes previously drilled, in the main line. The main line and the branches are then joined with silver solder. In use this assembly is subjected to an internal pressure of 40 to 50 lb. per square inch, and it must of course be absolutely leak-proof and vibration-proof. Because of the relatively high melting point of the silver solder and the high heat conductivity of the copper, the oxy-acetylene flame has been found best for producing a perfect joint quickly.

Oxy-acetylene welding is also used to a certain extent in assembling fenders, where it has the advantage of not burning through the metal or leaving rough marks on the topside, that would have to be polished out.

Rear Axle Housings are commonly made in two halves that are welded together either by the oxy-acetylene method or by electric arc or resistance welding.

Body

Comparatively much more welding, both electric and oxy-acetylene, is used in the body than in the chassis of a motor car. Which method is chosen for a certain application depends largely on the number of units manufactured of the model in question.

In high grade sedan bodies of the composite type, that is, bodies built up of metal panels over a wood frame, the largest individual part is the back panel. Because of its size and shape it is in shop parlance known as the "balloon." It encloses the whole rear portion of the body, from one rear door hinge pillar to the other and it also takes in the wheel housings and part of the roof.

As it comes from the press shop, it consists of three pieces: two rear quarter panels and one center panel. If the rear quarter panels alone were to be placed on the body frame, they would extend from the rear hinge pillar to a line which would be an approximate continuation of the inner roof panel line. The center roof panel would fill up the space remaining between the quarter panels.

Ordinarily, however, the three panels are welded together to form the "balloon" before they are assembled to the body frame. On sedan bodies the welding is commonly done in an electric butt welding machine. This machine has four sets of jaws shaped to the exact contour of the panel it holds. One set of jaws clamps each edge of the center panel, the other two sets each

clamp one edge of the quarter panels. The panels are held a fraction of an inch apart, but as the machine is started the jaws are connected with the welding current, a cam action moves the panels together and the entire length of the seam is fused at once.

This is a very fast and economical method where production is large enough to warrant the investment required, but even so the operation is not complete without the use of an oxy-acetylene torch, for this reason: The weld is nowhere thicker than the individual panels, that is, 16 to 18 gage and therefore it is common practice to reinforce the top and bottom ends, which are subject to severe strains, from twisting and racking of the body, by acetylene welding a short bead on the inside of the panel. Where production is relatively small and the weld short, as in coupe and roadster backs, it is often found practicable to use oxy-acetylene welding entirely in assembling the back panels.

In this case, the three panels are placed in a relatively inexpensive jig which locates them in their proper relation to each other. At the weld line they are backed up by a heavy cast iron form in which a shallow groove is cut. The panels are held against this form by a clamp which has a slot for admitting the welding torch. The welding is done from the topside of the panel, and after it is complete, the weld is beaten down into the before-mentioned shallow groove, with a suitable tool. It is then freed from scale and welding flux with a power-driven wire brush wheel, and given a coating of tin with the assistance of a gas blow torch and a wiping rag.

The indentation in the panel is then filled with a molten 35–65 solder, which is worked with wooden paddles dipped in linseed oil to the approximate contour required. Lastly, files and power-driven portable sanders are employed to finish the panel to its exact contour, after which it is ready to be assembled to the body frame.

The next largest component part of a body is the cowl. This may be a single stamping, but is often made in three pieces, namely, two side panels and a top panel. The pieces are welded together either by oxy-acetylene process or electrically. In either case the procedure is identical in principle to that used for the back panels.

Another important weld is the one that joins the roof panel and the back panel. On Graham bodies, this is a case where the oxy-acetylene process so far has been the only successful welding method. The welding must be done after the panels are assembled to the body frame. This eliminates any form of electric resistance welding. Furthermore, because the panels are backed by a solid wooden roof rail, there is no room to apply the copper backing necessary to successful arc welding on sheet metal. This leaves the field open for oxy-acetylene welding, and it does the job quite efficiently, and with very little damage to the underlying wood.

In many cases oxy-acetylene welding is very helpful in the building of special or custom bodies, using standard panels. If it is desired, for instance, to build a body with a rear seat slightly wider than standard, the standard center back panel may be split, a strip of body metal of the proper width inserted between the halves, and the pieces acetylene welded together. In a case of this kind, considerable care must of course be taken in smoothing the surface by means of grinding wheels and sanding machines. All waves in the metal, caused by expansion and contraction strains, must be removed by hammering, and all blowholes must be filled with solder, before the lacquer finish can be applied. Nevertheless, this method is usually much less expensive than the making of a whole special panel by hand.

In construction and maintenance work in connection with plant equipment, the oxy-acetylene process, both for welding and for cutting, is of course almost indispensable.

It is put to use in welding broken machine frames, building and moving conveyors, building stock racks and machine platforms and in installing pipe line branches where no tees are available in the main line. It is used in the building of jigs and fixtures and in welding high speed steel cutting tools to mild steel holders.

It may be interesting to recall a few actual cases where oxy-acetylene welding effected savings out of all proportion to its cost.

A conveyor, for assembling and finishing doors, was being installed at the Graham-Paige Motors Corporation body plant in Wayne, Michigan. It was what is known as an apron type conveyor. The doors were to be laid flat on top of it, first with the inside up, for assembling the lock board and window regulator, then they were to be turned over so that the outside was uppermost, in position for metal finishing. Furthermore, the doors had to be clamped to the conveyor to assure that they would move along with it.

At first it was intended to use a commercial toggle joint clamp, commonly found on jigs and fixtures. This was to be mounted on a hinge to allow for turning the door over. The idea probably would have worked very well, but 96 clamps were required, costing $15.00 a piece installed, or a total of $1440.00.

So, instead, a cam clamping device was designed that could be made of standard angle iron and round and flat bar stock. This was assembled with the help of oxy-acetylene welding at a cost of $120.00 for the 96 clamps, a saving of $1320.00 over the method considered first.

Another time the cast steel elbows that join the blow-down valves to the mud drums of two Springfield water-tube boilers developed leaks at the flange that is riveted to the mud-drum. The joint could no longer be calked, as this had already been done several times with the result that the flange had an inward instead of an outward bevel, and further calking merely aggravated the trouble.

Simply welding the flange and the mud-drum together would seem to have been the obvious remedy. This did not meet with the approval of the boiler inspector, however, for the very good reason that a weld around the outside of the flange would not prevent a continued attack of corrosion on the rivets and the already badly fitting surfaces of the mud-drum and the flange where they adjoined each other. He suggested that the old castings be scrapped and new ones installed.

Instead of this, the castings were removed from the drums, and the circumference of their flanges built up with successive layers of welding beads, to a point where they could be ground to the necessary outward bevel for calking, and still retain their proper diameter.

A template was then made, accurately corresponding to the contour of the mud-drum. The flange was fitted to the template by means of a very light shaper cut, followed by grinding. This also served to put a sharp corner on the built-up edge of the flange.

After re-riveting the elbows in place, the built-up flanges were calked to the mud-drums, making a joint that is absolutely tight and in every respect as safe and satisfactory as could have been obtained with new castings. And, incidentally, in resurrecting the old ones, the cost of several welding outfits was saved.

In building motor cars, large numbers of portable electric tools, such as drills, screw drivers and disc sanders are used. These usually have cast aluminum gear cases which are subject to considerable breakage from rough handling. The average cost of replacing one of these gear cases is approximately $12.00. With the aid of an oxy-acetylene welding torch they can almost always be reclaimed at a cost of less than one dollar.

There is, of course, a wide variety of oxy-acetylene equipment used in the motor car industry. Small welding torches predominate, however, with tip orifices ranging approximately between 0.031 in. and 0.086 in. in diameter. Only a small amount of oxy-acetylene machine welding is being done, and cutting torches are almost entirely confined to construction and maintenance work.

Where a sufficient quantity of oxygen and acetylene, to warrant the installation cost, is used, it is customary to distribute the gases through pipe lines. If only small amounts are needed, or the operations are moved frequently, it is, of course, preferred to serve each job from standard individual pressure containers. In this case, each welding outfit is equipped with a gas economizer that automatically shuts off the gas when the operator hangs up his torch. It has been found that even on production welding on moving conveyors, the use of gas economizers effects an average saving of 50% in oxygen and acetylene.

While the automobile industry as a whole uses less gas welding than electric welding considered on a percentage basis of the number of inches of welded joints produced, the oxy-acetylene process has nevertheless a well-established field; and, as long as present conditions continue to prevail, because of its low initial cost, and versatility, it will be indispensable.

Allegheny Metal in Dairy Equipment

By L. W. HOSTETTLER

†Extracts from an address presented by Mr. Hostettler, Engineer of the Allegheny Steel Company, at the National Dairy Exposition, Atlantic City, N. J., October 29, 1931.

About five years ago the Dairy Industry first heard of the Austenitic chromium nickel iron alloy, commonly known now as "18–8" and produced by several companies under their own trade name, such as Allegheny Metal.

At first there was no definite knowledge from actual service in connection with this alloy, but exhaustive tests were made in various laboratories in comparison with other available metals used in the manufacture of dairy equipment and the result of these tests showed the 18–8 to be by far the best of any of the metals tested, being insoluble in milk products themselves and most resistant to the chemical sterilizers and brines used in dairy plant operation.

First Methods of Fabrication

The first efforts in the fabrication of this alloy were not very successful as it was found that the conventional lock-seamed and soldered joints were not permanent and the solder or tin soon broke away from the base metal, particularly on equipment which was subjected to temperature changes or breathing.

This condition might have been anticipated in view of the physical characteristics of the alloy. A metal with a high tensile strength about 90,000 lb. per square inch, a high coefficient of expansion, and a very low thermal conductivity, is not particularly adaptable to the soldering and tinning process. The resistance of this alloy to the ordinary soldering fluxes does not permit of good penetration and therefore, as a rule, soldered joints are not dependable.

Oxy-Acetylene Welding

When it was found that lock-seamed and soldered joints were not practical the fabricator naturally turned to welding. Here, again, the tendency was to use too light a gage of metal, necessitating the oxy-acetylene method of welding. Difficulties were encountered in actual practice. It was found necessary to use a slightly reducing flame to produce porous-free welds which flame is difficult to maintain. Moreover, it tends to produce an excess of carbon in the weld metal itself.

Another problem in oxy-acetylene welding is to keep the piece from either buckling or building up excessively high work strains. Obviously, when welding a metal with the extremely high expansion coefficient of 18–8 this is bound to occur as the oxy-acetylene flame heats a much greater area of metal than the arc method. Being very much slower, the heat naturally travels a greater distance into the body of the piece on both sides of the weld.

To overcome the buckling, wrinkling and going out of shape it is therefore necessary to use jigs and chill plate.

However, it is not altogether impossible to oxy-acetylene weld the 18–8 Alloy and the following is the best technique to follow:

1. Use an uncoated rod of 18–8, preferably of a low carbon content (not exceeding 10) and with chromium content not less than 19.00% and nickel content not less than 8.50%.
2. Use jigs and chill plates.
3. Use tips one or two sizes smaller than for same job in mild steel.
4. Use tips that have not been reamed to a point that spreads the flame fanwise.
5. Use gages that are in good condition.
6. Use a soft slightly reducing flame.
7. Do not puddle, as porous welds will be a sure result.
8. Direct the flame at a slight angle in the direction of the weld to be made.
9. Use a filler rod whose diameter is approximately the thickness of material being welded.

Arc Welding

Properly used arc welding was found to give much better results.

It was found, however, that it was impractical to weld lighter than 16 gage (0.062) by this method. In fact it is only during the past year that it has been accomplished commercially and is the direct result of experience and requires extreme care on the part of the operator. Number 14 gage (0.078) is much easier to handle than the lighter number 16 gage and the average welder finds that number 12 gage (0.109) is the ideal thickness, as he has sufficient metal to work with and when the bead is ground off there are practically no blowholes to spot.

The 18–8 Alloy has a very high electrical resistance (about 415 ohms per circular mil foot) and this characteristic lends it to electric arc welding. The operator finds that less power input is necessary than with steel or other metals with a lower electrical resistance and that the metal flows much better.

The following technique is suggested to attain the best results:

1. Reverse polarity (work to be the negative (−) electrode).

2. Select a machine, if possible, with the greatest range of power input control.

3. Use an 18–8 fluxed or coated filler rod with a maximum of 0.10 carbon and a minimum of 19.00% chromium and 8.50% nickel. The flux should contain no carbonaceous compound. This to prevent carbon build-up in the weld metal.

4. Use a medium short arc with just enough power input to maintain the arc. This short arc and minimum power input is harder for the operator to handle, but gives better flux protection to the molten metal and a much sounder and porous-free weld as there is not the tendency for oxide to pollute the weld metal. It is also a trifle slower than if more power were used, but the additional time is more than compensated for by the absence of pinholes.

5. Have the metal to be welded clean and entirely grease-free.

6. Before striking an arc with a new filler rod in continuing a weld, removing of the oxide on the welding bead will be a decided aid in preventing a pocket or pinhole at this point. A stiff wire brush is used by some operators, but the best results are really attained by using a high cycle light weight electric grinder, with a soft wheel.

With the lighter gages, it is general practice to weld from the back or unpolished side of the sheet, using power input sufficient to get uniform depth of penetration for the subsequent grinding of the bead on the penetration side. On number 12 gage and heavier, however, it has been observed that the fabricators who weld on the inside (polished surface) first, using a short arc and minimum power input, with no attempt to get any depth of penetration and then run a bead on the back (unpolished surface) with normal penetration and build-up bead for strength, get uniformly better results, so far as pinholes and pockets are concerned. However, this is, of course, a matter for the individual welder to decide for himself.

The metal arc method with the proper filler rod and technique produces a porous-free ductile weld of good physical characteristics and practically no carbon pick-up.

Grinding the welded bead is best accomplished with a soft free-cutting bonded wheel.

This wheel has less tendency to "heal over" any pinholes in the weld. It is necessary to entirely bottom out all pinholes, since, if this is not done, the metal will become discolored from the oxide remaining, and a galvanic cell action may be set up. The pinhole should be bottomed out so that it will not accumulate dirt and bacteria.

Resistance Welding

Manufacturers of resistance electric welding equipment have made rapid progress in the development of this type of equipment for line welding, butt welding and spot welding the 18–8 Alloy and it is recommended that the manufacturers of dairy equipment investigate line welders since they are extremely rapid and give perfect welds with a minimum of grinding after welding, thereby lowering costs.

While the welding operation in itself is readily accomplished, sound, ductile, porous-free welds resulting and the weld metal itself being perfect, there may occur, however, a change in the metal immediately adjacent to the weld in the zone where it has been heated to a temperature in the neighborhood of 1200° F., which may cause weld decay or intercrystalline corrosion within the localized area mentioned above.

To successfully apply this alloy to any given service it is necessary that this phenomenon be thoroughly understood.

The 18–8 Alloy is austenitic, and therefore nonmagnetic, the carbon being in solid solution. It is quite stable at ordinary temperatures, but when heated within a certain range of temperature, the carbon tends to dissociate and separates, presumably as carbide, between the crystal boundaries. This precipitation or dissociation of carbide is dependent on temperature and composition.

The indicated temperature range at which this occurs is from 800 to 1200° F. The lower limit is not definite; unstable or so-called border alloys may dissociate at much lower temperatures. The length of time necessary to produce serious dissociation, by heating, is dependent on composition, but given sufficient time, all compositions will dissociate.

The precipitation of carbide does not impair the resistance of the alloy to corrosion except in active corrosive media, both liquid and gaseous.

Heating to 1800° F. or higher followed by rapid cooling will completely restore the metal and render it quite stable.

The carbon and iron content have a marked influence on the rate of dissociation. This is particularly important in the manufacture of welded equipment. In welding it is obvious that the area adjacent to the weld will be subjected to the temperature range at which dissociation takes place. If a final anneal is to be given, the composition is relatively unimportant, but if it is impractical to anneal, a composition must be selected which will be stable enough to retard the separation of carbide, and one which offers the maximum assurance of consistent procurement, taking into consideration the raw materials available, process of manufacture, and the cost of production.

Largest Welded Steel Bridge

†This article was prepared by the Technical Publicity Department of the Skoda Works, Plzen.

The illustrations show the new *road* bridge passing over two state railway lines—Prague-Furth i.W. and Prague-Cheb—and connecting the south and north parts of the Skoda Works in Plzeň. On the south side the road ascends on a concrete gradient, crosses the bridge and on the north side falls to the level of the work's road. Here, on account of insufficient space, it was necessary to erect a serpentine with two turns. The most interesting part of this job is the bridge itself, which is entirely welded without rivets or bolts. The bridge, weighing 143 tons, has a span of 161 ft. 5 in., width of 27 ft. 5 in. By comparative calculations it was found that in comparison with a riveted bridge of the same carrying capacity the saving in weight is about 30 tons. The loading tests were carried out on October 21st in the presence of official representatives of the Ministry of Railways, the State Railways Administration in Plzeň and of the Municipal Building Service. Under a load of 112 tons the sagging was 0.335 in., whereas the calculated sagging was 0.425 in., i.e., by $21^1/_2$ per cent more. This bridge is the largest existing fully welded bridge in the world, as the Chicopee Falls bridge in North America, the largest welded bridge known at that time, has a span of only 134 ft. 6 in. The main technical data and designs of these bridges, as well as of two framework bridges, those of Lowicz, Poland, and Leuk, Switzerland, are given below. The Skoda Works develop such constructions in a systematic manner and a large number of fully welded structures have already been executed.

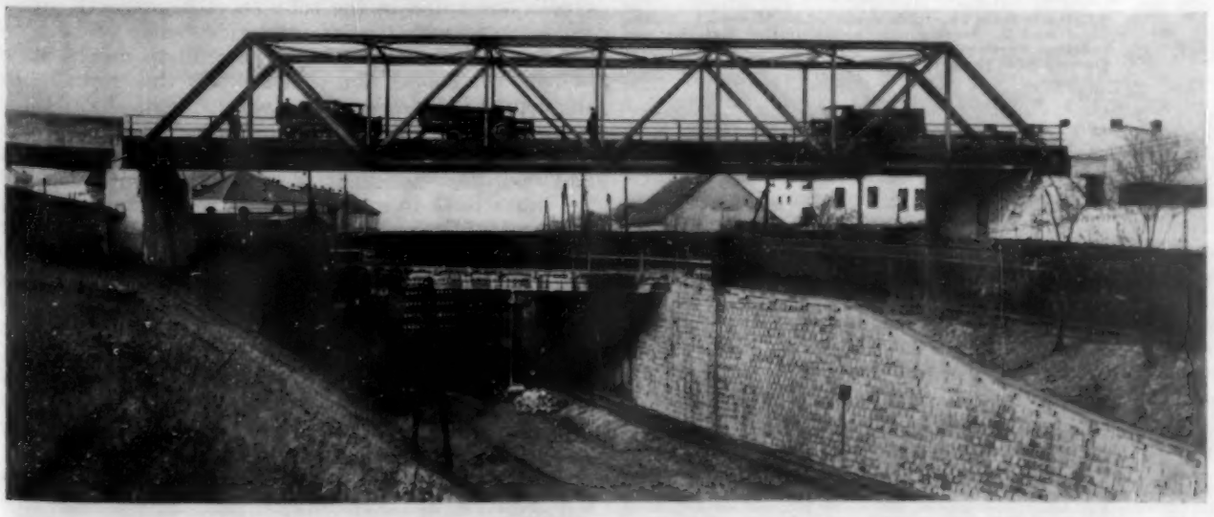
Top View of Bridge

Summary of the Largest Fully Welded Trestle Bridges Erected to Date

1. *Railway bridge near Chicopee Falls, U. S. A.* Length 134 ft. 6 in., width 17 ft. 1 in., weight 80 tons, surface in plan 2260 sq. ft.

2. *Road bridge near Lowicz, Poland.* Span 88 ft. 7 in., width 32 ft. 10 in., weight 55 tons; if riveted this bridge would weigh about 70 tons, surface in plan 3014 sq. ft.

3. *Road bridge near Leuk, Switzerland.* Span 121 ft. 1 in., distance of main girders 14 ft. 9 in., weight about 37 tons, width of roadway 19 ft. 8 in., surface in plan 2368 sq. ft.



Largest All Welded Bridge

4. *Road bridge of the Plzen Skoda Works*, at present the largest fully welded trestle bridge in the world. Span 161 ft. 5 in., width 27 ft. 5 in., surface in plan 4413 sq. ft., weight 143 tons.

Other Structures

Erecting shop of the Avia aeroplane factory, Cakovice near Prague. Area of building 97,000 sq. ft., total weight of the structure 276 tons. Span of arches, composed of perforated girders, 78 ft. 9 in.

New pattern store of the Skoda Works in Plzeň. Two 2-ton electric cranes. The crane bridges, as well as the travelling bridges, are composed of electrically welded perforated girders. Saving in weight, about 29 per cent.

Sheet pressing shops in the electrical engineering factory in Doudlevce near Plzeň. The structure was entirely welded in the shops and at the erection site. Five-ton electric crane of 36 ft. 9 in. span, also completely welded.

Ten-ton electric crane, span 41 ft., in the cleaning shops of Smíchov foundry. The cab and crane bridge are electrically welded. Saving in weight as compared with the same structure riveted, almost 2 tons (20 per cent).

Assembling an erecting hall structure, completely welded in the workshops and at the erection site. Area of building 8800 sq. ft. Roof structure (65 tons) of perforated girders.

Completely welded roof structure over the hall of the Skoda Works' own Hotel in Plzeň. Span of the main girders 42 ft.

Completely welded frame of an accumulator locomotive for the Czechoslovakian State Railways. Speed 25 m. p. h., weight 60 tons. Welding resulted in greater stiffness of the frame, at the same time reducing the weight.

Completely welded pontoon (65 ft. 7 in. × 15 ft. 9 in.) of a floating bucket dredger for 65 cu. yd. per hour. Electric welding was also used on many other spots of the dredger structure.

Evaporator station of the Malaga sugar factor (Spain). The first two bodies of large diameter are of welded parts bolted together; all the rest is welded in the shop.

Welded boiler for impregnating electric cables. Diam. 10 ft. 10 in., height 3 ft. 11¼ in., thickness ¾—1 in. Unit weight 11 tons.

Completely welded reservoirs for 660 gallons each, diam. 4 ft. 5 in. Ninety such reservoirs have been delivered to the Naftaspol.

Synchronized asynchronous motor of 1300 kw, 3000 v, 50 per., 250 r. p. m. Motor with two free ends. The shaft is intended for the drive of two wood grinding machines. The stator housing is electrically welded.

Electrically welded building crane of 24 cwt. up to 3 tons lifting capacity. Maximum span 65 ft. 7 in., height variable from 49 ft. 3 in. up to 147 ft. 8 in.

The Use of Oxy-Acetylene Welding in the Repair of Copper Fire Boxes of Locomotive Boilers

By **L. SACCOMANI** *and* **R. VERZILLO**

†Extracts from an article prepared by Messrs. L. Saccomani and R. Verzillo, Engineers of the Material and Traction Service of the Italian State Railway (Rivista Tecnica delle Ferrovie Italiane).

Introductory Remarks

The welding of copper in the repair of fire boxes of locomotives presented, until a few years ago, serious difficulties, and, therefore, had not been regularly practiced in our workshops, chiefly because copper, in comparison with iron, is more difficult to treat, owing to oxidation at high temperatures, to the great loss of heat caused by the high thermal conductivity of copper,[1] and to the great reduction in strength of copper when heated, as the metal near the zone of fusion becomes fragile.[2] When subjected to prolonged and excessive heating, the degree of crystallization is notably increased, and, further, overheating and even burning may take place. The tendency to oxidize increases rapidly with the rise in temperatures.

The oxide which is formed produces a coating of black flakes, which, at high temperatures, are converted into sub-oxides. These, which are soluble in molten copper, appear in several forms in the weld after its solidification, and render the metal fragile.

During welding, the great expansion of copper through heat is such that fracture readily occurs through internal irregularly distributed stresses.

Alive to the importance of the great advantages to be derived from being able to weld the fire boxes, our repair shops have been actively engaged in research work. The expense of locomotive repairs is well known, and the effect of this important item is further increased on the Railway Balance Sheet, by the loss sustained through the locomotive being idle.

The principal defects found in copper fire boxes are cracks and splits in the tube sheet between the tubes, similar cracks in the top and side bends of both the front and back of the fire box, corrosions around heads of both the copper and iron stays of the crown, under the copper ferrules, splits between the stay bolt heads, corrosions and thinning of the plates near the rivets. These defects give rise to frequent and costly repairs, and each year hundreds of locomotives with defective fire boxes have to undergo heavy repairs.[3] Very great savings could be realized if it were possible to weld cracks in plates and fill up corrosions in the fire boxes in locomotives in depots without having to take out the boilers.

The Material & Tractions Service, therefore, conceived the idea of diligently studying the technique of copper welding and of making repeated trials and experiments under the most rigid control, and, furthermore, of examining what had been done abroad in those quarters where this subject had been a matter of particular study.

[1] The heat conductivity of copper is 4 times that of iron.

[2] The strength of copper decreases at 100° C. by 15% and by 30%, 50% and 65%, respectively, at 250°, 450° and 530°, and if the copper is kept at a high temperature for any length of time this percentage increases.

[3] As an example, it may be mentioned that on checking up 500 of these, 25% of the boilers called for a complete renewal of the fire box, whereas a large portion of the remainder required fresh tube sheets, back plates and half sides. To be more precise, the tube sheets of 320 boilers, the back plates of 100 boilers, and the half sides of 180 boilers were changed.

Welding of Fire Boxes

The results obtained in our works from various experiments at different times up to 1923 were not satisfactory. The tests made by the "Institute of Experiments" on welded samples showed that the copper contained enclosures of oxide, and that there were large and medium crystallizations. Tests gave a maximum breaking load of 16 kg. per sq. mm. with 12% elongation. With a view to eliminating the difficulties of a physico-chemical nature referred to above, greater care was exercised in the use of oxygen and acetylene, which had the highest degree of purity;[4] the part to be welded was carefully cleansed—scraped and wire brushed—and the blowpipe flame was carefully regulated so that it would remain constantly neutral, i.e., with the inner flame elongated as far as possible, and of a bright white color with sharp edges.[5]

For the de-oxidation of the metal, experience showed the utility of using a flux, a mixture of borax, boric acid and chlorate of soda, and also a special filling rod containing a percentage of 0.4 of phosphorus. Phosphorus combines with the oxygen of the oxide of copper, and by a series of reactions phosphoric acid is produced, leading to the formation of phosphates, and which, with the other oxides, is eliminated as a slag.[6]

It being known that the German State Railways were using a copper filling material composed of special alloy of pure copper, with about 0.10% of phosphorus, about 0.20% of silver and traces of other metals, this was experimented with, using simultaneously as a flux a special paste made of borax, boric acid and chloride of calcium and soda, supplied by the same firm, this mixture being applied to the material to be welded, and to the filling rods.

In order to give to the molten copper filling rods, in the greatest measure possible, the mechanical characteristics of rolled copper, and in order to obviate the inconveniences of the lack of equilibrium in the internal tensions in the contraction when cooling, and the enlargement of the crystallizations, it was found necessary, after the welding, to hammer well, followed possibly by a reheat to nearly 600° C. with subsequent cooling. Trials on bars as described above gave results such as a hardness of 6.2 kg. per sq. cm., a tensile strength up to 21.3 kg. per sq. cm. with 43% elongation and 55% contraction, as compared with 21.7 kg. and 39½% elongation and 35% contraction of the original unwelded copper.

These experiments were repeated at the works, and the same satisfactory results having been obtained, it was decided to make the first application to locomotive boilers in service (July, 1924).

These repair jobs were kept under close survey for a reasonable time before making further applications. This period of experiments of the boilers in service showed that the results were fully satisfactory, and further applications were then carried out on an extensive scale.

After the welders and the engineers had arrived at a sufficient degree of skill in the Oxy-acetylene welding, experiments were made of filling material of electrolytic copper in place of the special filling copper, "Kanzler," and without using the special flux.

We examined the bars thus welded, the results being found satisfactory (tensile strength 20 to 22 kg. per sq. cm. with 29 to 31% elongation).

These results justify the extensive use of pure electrolytic copper as a filling material in the welding of fire boxes of locomotives.

Theories exist which claim that the so-called neutral flame has a reducing power, which would appear to be confirmed by the excellent results obtained on perfect welds, using pure electrolytic copper without flux.

By September, 1927, 924 locomotives had the fire boxes repaired by Oxy-acetylene welding on 332 of which pure electrolytic copper was used for filling.

Of the said 924 locomotives, there has not been one single case of real non-success; in some of these, however, only some minor cracks have been formed. The percentage of these, after rigorous analysis of the first 500 repaired locomotives, is about 5%, partly fire boxes repaired by welding, for which the filling material, "Kanzler," was used, and partly those repaired by welding for which pure electrolytic copper was used. Over and above the repairs referred to, we have built two fire boxes which have been completely welded without riveting. These were fitted on the locomotives Nos. 685,043 and 420,293, which have been in service, respectively, since April 25, 1927, and July 11, 1927, and these are being constantly kept under close survey.

The welded fire boxes, owing to the elimination of riveting and calking, offer the unquestionable advantage of water-tightness and economy in the upkeep of the plates. Purely as an experiment on these furnaces, the heads of the copper stays have been welded from the copper side, and only a small number of stays were fixed in the usual manner.

The behavior in service of the two fire boxes as above described has so far been satisfactory.

The small percentage of minor defects or breakages, which the continual inspection under service conditions revealed after the execution of welding, indicates that a high degree of perfection has been obtained in the special technique of Oxy-acetylene welding of copper.

Control and Inspection

Repairs to fire boxes of boilers by means of oxy-acetylene must be first proposed by the workshop and depot department to the Head Office of Service, and cannot be undertaken without its authorization. The Central Head Office of the Service then decides either to execute or superintend special jobs. A report on each repair is registered at the Central Office of the Material & Tractions Service, with indication of the quality of the filling rod used, and a record is kept, with sketches, of the repairs executed by welding. A copy of these sketches is attached to the log book of the boiler. Welds in locomotive fire boxes are kept under close observation while in service, and, for this purpose, a register is kept by the department to which the locomotives belong, so that a careful inspection can be made by engineers appointed for the purpose, two months from the date of each weld executed, and, subsequently, at periods of 4, 6 and 12 months. The various sections are required to give a detailed report to the Central Office of the Material & Tractions Service of any defects which may be found. This report must be sent in at the end of each 12 months' service, even if no defects have been found.

Economic Advantage

The saving achieved by repairs being executed at the locomotive depots is self-evident, because it permits of deferring for several months the sending of the locomotive to the workshops for general overhaul, which means that the locomotive may remain longer in service, with great advantage to the Railway Administration,

[4] Impure acetylene may produce highly injurious sulphides and phosphides.
[5] When the inner flame is short and of a bluish or reddish color, the flame has an excess of oxygen and the weld is burnt.
[6] The phosphorus must not, however, remain alloyed with copper, as it would form a phosphide, which, encircling the copper crystals, would produce an extremely fragile material.

both on account of the minor costs of repairs within a certain number of years, and also because of the shorter periods during which the locomotive is idle.

While repairs by means of Oxy-acetylene Welding of the damaged sheets and plates are always advantageous at the locomotive depots for the reasons above given, these repairs by welding may be executed at the general over-haul at the workshops, but, of course, only in such cases where the general condition of the plates and sheets are such as to warrant the reasonable expectation of their remaining good until the next general overhaul.

Operators and Technical Particulars Regarding the Work

Experience has shown that, to obtain good results from a weld, the principal contribution comes from the welders. They must be chosen with every care, and it is well that their ability be examined before entrusting to them the repairs of boilers in service. They should be required to carry out trial welds on plates not being used, which should then be subjected to tests (of bending, tension, etching by Nitric Acid).

It is indispensable, also, that the engineer or foreman who is directing the work and superintendent welders should have a thorough knowledge of the technique of welding, of the manipulation and construction of the apparatus and appliances necessary, and that he be able to judge the quality of a weld executed, while it is being done.

While welding often appears to be simple, in reality each case has its own difficulty, which calls for measures to be adopted and which may only be obvious to one who has had experience in work of the kind.

A practical welder must be able to judge and choose for each job the blowpipe best adapted from those which are placed at his disposal.[7]

The welders must work in pairs and proceed with the work in perfect coordination and with full comprehension of what the other is doing; one must direct the welding and the other must be the intelligent executor, ready to obey immediately what is requested of him.

When a weld has been completed from one side only, generally on the side of the fire, there must be only one welder to fill in with the welding rod; the other welder with the blowpipe must attend to the neighboring zones or the part opposite that of the welding course, paying attention that the temperature is adequate, and when he finds that a certain point is excessively heated, he must withdraw the blowpipe, and pass it to pre-heat the part which follows and which is subsequently welded.

When it is possible to work on the opposite side of the crack, the second welder will apply the welding rod to said part, so as to avoid that when the hammering is being done on both sides, the thickness of the sheet is not diminished. The blowpipe of the worker who is welding must be maneuvered parallel to the welding seam, and the operator must proceed, with long welds, in a receding plane, i.e., receding from the part welded, and in vertical welds from below upward, in order to avoid the molten metal running in the furrow to be welded.

The worker who is engaged only on pre-heating must pay great attention not to disturb or hamper with his blowpipe the work of his companion.

If a weld has to be made of a certain length, it should be done in sections; after about 10 or 15 cm. of welded seam, the blowpipe should be extinguished and dipped into a bucket of water to cool the tip, otherwise the heated tip may cause trouble during welding, and the hammering of the welded section must be done immediately, and it must be extended to the bordering zones, which, however, must be hammered again after welding.

Each time the workers have to light the blowpipe, it must be done with a match or torch, and the welder must avoid playing on the surface to be welded with a cold jet from the blowpipe.

When, however, a weld has to be done on both sides, as in the case of cracks in the tube plates, one welder takes up his post from the furnace side, and the other on the side of the boiler valve. Each welder must have at his disposal a bucket of water and two hammers (one spherical and the other flat), a chisel, a gouger, a filling rod, a metal brush, etc. They will each weld simultaneously the seam to be welded, each one on his own side, and in each chamfer previously chiselled and bevelled. The filling material must be applied in such quantity that, after the hammering is done, the weld shows a convex thickening, with ripples of 2 mm.

The hammering must be begun with hammers with spherical heads of about 400 g., and with a very quick rhythm and light blows, and to be terminated with hammers of about 1 kg. with flat heads.

The hammering must cease when the weld loses color, and it must be done simultaneously from both sides in the same place, so as to consolidate the plate without causing any stress to one surface or the other by the hammer blows not being applied simultaneously.

In every case, the weld, when cooled, must be cleansed thoroughly with the chisel and gouge. When it is possible, particularly in lengthy welds, the hammering of the welds should be done with a light pneumatic hammer.

The inspection of a weld should be made with a good magnifying glass, to ascertain whether there are traces of cracks, in which case the defect must be gouged out to the bottom so as to proceed with the new weld. Wherever possible, the plates should be annealed, so that, at the least welded part, it has a temperature of 600° C.

The work the welders have to do is always heavy, and it is therefore necessary not to request of them excessive efforts, and they should be provided with all comfort, to reduce the strain, such as asbestos gloves, asbestos-fibre coating for the chest, aprons, etc.

It is obvious from the foregoing that the welders must undergo a special course of training to be able to attain sufficient skill. The Material & Traction Department has instituted special classes for this class of work, and these are attended by welders who have shown proficiency in general welding.

Conclusion

1. In tension tests, the X-welded bars gave better results than the V-welded ones, and only a slight difference was noticeable between the annealed and the non-annealed bars.

2. The results of the bending tests were not satisfactory, especially the flat non-annealed bars.

3. The impact tests gave good results, relative to the rough state of fusion in which the weld is generally found.

4. Under a microscopic examination, it was found that the welds were without these defects which usually accompany same.

[7] Tube plate was in a very bad condition and should have been changed. After the repair by welding, the locomotive remained in active service another 22 months.

Variation in Battledeck Floor Constructions

By A. F. DAVIS

✦Mr. Davis is Vice President of The Lincoln Electric Company.

Des Moines Building

A variation of the usual method of steel "battledeck" floor construction is the feature of the new office building of the Pittsburgh Des Moines Steel Company at Des Moines, Iowa. This type of construction, long used on the charging floors of open hearth furnaces, consists of the substitution of welded steel plate and I-beams for heavier construction materials commonly used in flooring. Battledeck flooring makes possible a lighter and less expensive building with distinct advantages in strength and rigidity.

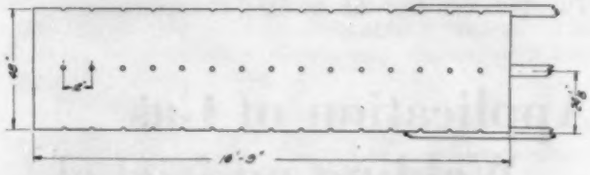


Fig. 1—Floor Plates Were $^3/_{16}$ Inch Structural Steel Plates Punched as Shown. Plates Carried on 3-Inch I-Beams

With this floor it is possible to determine in advance the stresses in all parts and which will recover instantly to a full 100 per cent of its deflection due to live load when that load is removed.

The new building in Des Moines is a three story structure 100 feet by 50 feet. The steel frame is of the traditional riveted construction but the flooring is of the battledeck type. This flooring is carried on 3 inch I-beams on $24^1/_8$-inch centers which are supported by the girders.

For the floors, $^3/_{16}$-inch structural steel plates, 16 feet 9 inches by 48 inches, were specified. On the job these plates were not squared or planed but were used just as they came from the mill. These plates were punched in the center of the plate with $^{11}/_{16}$-inch holes on 12-inch centers. The longitudinal edges of the plate were punched with half holes as shown in Fig. 1.

After the plates were placed in position two of the full holes in the center plate were welded. The adjoining plates were then tack welded in the same way, after which the center plate was fused to the three I-beams which it spanned. This procedure was followed on each floor, working from the center of the building outward. Each hole required less than 30 seconds of welding with $^3/_{16}$-inch electrodes. The heat at which this welding process is applied insures deep penetration. A 300-ampere welder supplied the welding current. A general view of both sides of this floor construction can be seen in Fig. 2.

A spacing of $^1/_4$ inch was allowed between the ends of the plates. These plates were fused into the supporting member with 2 inch stitch welds. The floor plates

Fig. 2—Showing Both Sides of Battledeck Floor. Notice Stair Wells

extend $2^1/_2$ inches into the exterior walls of the building.

Annealed plates were ordered in order to forestall buckling, although the structural engineers now believe that this precaution is not necessary. On the job a 400-pound roller was rolled just behind the hole being welded. This is shown in Fig. 3. As a further precaution each weld was peened before rolling. This was done to counteract shrinkage strains.

As a result of these precautions only three of the 3-inch I-beams were buckled and these so slightly that they were straightened by welding a bead below the flange. These buckles all occurred on the ground floor which was the first to be constructed.

Inasmuch as these floors were laid before work was started on the masonry walls, it was not necessary for the masonry contractor to go to the expense of erecting scaffolding and false floors. A $^1/_{16}$-inch layer of mastic cement was poured on the steel floors and the whole covered with $^3/_{16}$-inch tile after the walls were completed. Plaster ceilings, fireproofing the steel and covering the conduits and piping were suspended from the lower flanges of the 3-inch I-beams.

The welding and steel erection was done by the owners of the building. Two welding operators were used. This type of flooring weighs 11 pounds per square foot. Concrete flooring of the same strength would weigh 33 pounds per square foot.

The use of battledeck flooring allows many economical advantages. It is estimated that on a building of 75 stories with floor panels of $21^1/_2 \times 22^1/_2$ ft. the saving in dead load on the foundations of each column would be nearly 2,000,000 pounds. The steel floors, welded into a single unit, serve as a girder to prevent tortional distortion if the building is subjected to wind or earthquake action. The steel plates may be surfaced with any number of materials and the ceilings may be con-

Fig. 3—Welding with Shielded Arc Process on Battledeck Floors. Helper Peens Weld and Follows with 400 Pound Roller

Fig. 4—A Section View of the Wood Sleeper Affixed to the Steel Floor Plate with a Threaded Nail

structed either of metal lath and plaster or pre-cast concrete hooked to the lower flanges of the I-beams. This type of construction has been indorsed by the American Institute of Steel Construction as an efficient and practical building method, and its use hailed as a sign of intelligent and progressive engineering.

Cleveland Demonstration

Possibilities for variations in design of battledeck steel floor construction were also exhibited before building experts, structural engineers, welding technicians and officials in charge of construction for the Cleveland Board of Education in a demonstration recently conducted in Cleveland.

An innovation was the introduction of a method of affixing wood sleepers to the steel floors. In most cases, where a wood floor is not necessary, it has been customary to surface the steel plates with cork or tile. The use of wood sleepers not only allows wood flooring but, in residence building which is now turning to steel frame construction, provides a floor construction which offers the minimum of obstruction to pipes and conduits.

Wood 2 × 4's are laid on the plates and drilled. The drill goes through the wood and the plate. A patented nail of special steel manufactured by the Hill Wood Manufacturing Company, Cleveland, Ohio, is then driven through the sleeper, threading itself into the steel as it is driven. This is shown graphically in the section drawing, Fig. 4. Tests to remove the nails by wedges under the sleeper resulted in tearing off the wood without bending or starting the nail. Figure 5 is an isometric drawing of this type of battledeck construction with plug welds, showing the position of the wood sleepers.

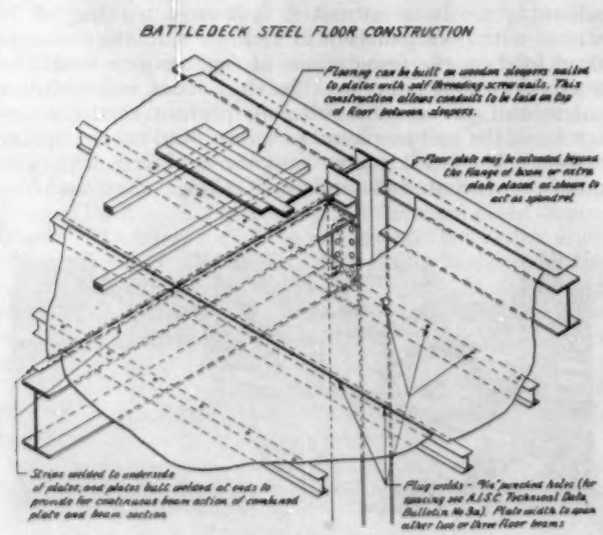

BATTLEDECK STEEL FLOOR CONSTRUCTION
Flooring can be built on wooden sleepers nailed to plates with self threading screw nails. This construction allows conduits to be laid on top of floor between sleepers.
Floor plate may be extended beyond the flange of beam or extra plate placed as shown to act as spandrel.
Strips welded to underside of plates, and plates butt welded at ends to provide for continuous beam action of combined plate and beam section.
Plug welds - 11/16" punched holes (for spacing see A.I.S.C. Technical Data Bulletin No 3a). Plate width to span either two or three floor beams

Fig. 5—Isometric Drawing Showing Battledeck Floor Construction for Manual Welding

The flooring in this demonstration consisted of 5/16-inch steel plates, 4 feet wide, punched 24 inches from the edge of the plate with 11/16-inch holes on 12-inch centers. Half holes were punched along the edges of the plates. This flooring was carried on 5-inch I-beams over a 20-foot span to support a live load of 75 pounds per square foot. The I-beams were spaced on 24 1/8-inch centers.

In this demonstration the floor plates were fused to the I-beams by plug welds through the holes.

The recent adoption of battledeck flooring in several large buildings has focused attention on this method of construction. With arc welded steel frame homes of practical design now possible, the innovation of a method of affixing wood flooring to the steel points to the spread of battledeck floor construction in residence building.

The demonstration was conducted by the Carnegie Steel Company in its Cleveland warehouse. The welding was done by The Lincoln Electric Company of the same city. This type of battledeck floor has been endorsed for structural work by Lee H. Miller, chief engineer of The American Institute of Steel Construction.

Application of Gas Welding on Nickel Plate Road

By **J. C. MILLER**

✦Paper presented before the 32nd annual convention of the International Acetylene Association, Chicago, November 11 to 13, 1931, by Mr. Miller, Superintendent of Shops, The New York, Chicago and St. Louis Railroad Co., Cleveland.

The material presented in this paper deals with the use of the gas welding process as used in the Conneaut Shops of the Nickel Plate Road.

It will no doubt be interesting to contrast or explain the amount of saving effected by the advent of the gas welding process as compared with the long-established process of blacksmith welding.

Frames

In the past when it was necessary to weld a broken frame considerable expense resulted from removing the frame from the locomotive and re-applying it after the blacksmith weld had been made. Contrast this procedure with the present-day gas welding method of repairing broken frames. In this process it is only necessary to remove the parts adjacent to the fracture. The material on each side of the fracture is removed by the use of the acetylene cutting torch, the cut being made in the shape of a "V" from both sides. The new surface thus presented is cleaned by the use of either a pneumatic chisel or the sand blast process. The next operation is securing the desired expansion which, of course, depends on the size of the frame. This is accomplished by the use of a small powerful jack developed

in our local shops. The last operation prior to the actual welding operation is placing a plate on the bottom side of the section to be welded in order to give a foundation for starting the weld.

In the actual welding operation two torches are employed, the operators working opposite one another. When the weld is made with steel the operators must be careful to have the ends of the fractured frame at a temperature which will permit the puddling in of the steel welding rod. When bronze is employed in making the weld the temperature of the frame ends must be such that the bronze will adhere properly—about 1600° F. The success of the weld depends on the experience and judgment of the operators. While we have no definite data on the cost of removing a frame from our modern class of power, we have every reason to say conservatively that a saving of 90 to 95% is effected by gas welding.

While we did use steel rod when making frame welds in the past, we have for several years been using Tobin bronze. The reason for this material being adopted lies in the fact that there is a considerable time saving effected as compared with the use of steel welding rod. In the period of time since the use of Tobin bronze steel was inaugurated there has not been a single case of the bronze weld breaking.

Cylinders

The next gas welding process of major importance at our shops is the welding of broken cylinders. This operation may be divided into two classes, with subdivisions as shown below:

1. Cylinders *not* removed from the frames.
   (a) Front of cylinders damaged by water blow.
   (b) Cylinders and valve chambers cracked longitudinally.
   (c) Valve chambers cracked circumferentially.
   (d) Cylinder and valve head joints built up.
   (e) Oversize cylinder and valve chamber studs welded up.
2. Cylinders removed from frames.
   (a) Cylinders cracked in frame fit.
   (b) Cylinders cracked in saddle.

In all the cases referred to above the cylinders are preheated, the extent of which, however, depends on the nature of the fracture to be repaired.

When building up defective cylinder or valve chamber head joints the preheating may be accomplished by placing a grate of front end netting half way up from the bottom of the cylinder of valve chamber and building a charcoal fire thereon. The outside of the cylinder must be covered with heavy asbestos paper to retain the heat developed and to prevent cold air from coming into contact with the heated cylinders. The balance of the various classes of fractures, in our opinion, should always have a brick furnace built around the cylinder. In this case a grate of front end netting is placed across the furnace wall about 6 inches below the bottom of the cylinder in addition to the front end netting grates placed within the cylinder and valve chamber. When building the furnace care must be taken to lay the two bottom rows of bricks with 1 in. openings between the ends in order to create the required draft. When the furnace and grate arrangement is completed, charcoal is placed on the grates and the fire started. Care must be exercised to have a slow burning fire in order to raise the temperature of all sections together which would not result in case the fire was forced at the start.

When preparing to weld a fractured cylinder which has not been removed from the locomotive and which has a brick furnace built around it, we find it is a very good rule not to start the welding until the temperature of the cylinder saddle adjacent to the flange has reached a temperature which will not permit the hand to be placed comfortably thereon.

In the case of the welding of a cylinder fracture when the cylinder has been removed from the frame the furnace is built entirely around the cylinder. The grate arrangement is the same as previously described. The top of the furnace around the cylinder is covered with several layers of heavy asbestos paper.

In the construction of furnaces around the cylinders it must be thoroughly understood that the construction be such as to permit easy removal of sections to afford access to the fracture. At the point above the base of the furnace where begins the section of brick which it is desired to remove, a strip of sheet iron is placed on top of the bricks. The furnace sides are continued upward, leaving an opening of sufficient width to permit access to the fracture. When the desired height of opening is reached a strip of heavy metal is placed on top of the bricks to support the upper rows of bricks used in completing the furnace. The opening thus provided is then bricked in with bricks laid with straight joints which permit easy removal.

While the welding is performed it is necessary to replenish the fire from time to time as the occasion may demand in order to maintain the desired temperature. When the weld has been completed the furnace must again be fired up and completely covered with asbestos paper and allowed to cool to room temperature before the asbestos paper and brick are removed.

When building up cylinder or valve chamber head joints it is our practice to use bronze. Likewise when building up oversize stud holes prior to drilling and tapping standard. The balance of cylinder fractures, with one exception, are welded with cast iron. The one exception is the case where the portion of the cylinder which rests on the frame rail has been so badly broken that it is necessary to replace the broken pieces with a piece of steel plate. In this case bronze is used as the cast iron welding rod would not make a satisfactory bond between the steel plate and the cast iron.

When repairing fractured cylinders with either bronze or cast iron we have never had a failure since we adopted gas welding on cylinder reclamation. We believe the secret of our success lies in the care we exercise in the preparatory work. Of course, we appreciate that it is necessary to have experienced, skilful operators and, last but not least, good material.

Considering the saving effected by the gas welding process I will say that carefully compiled reclamation costs on a pair of cylinders removed from the engine showed that the cost of reclamation was only 25% of the cost of new cylinders. It might be interesting to know that this work was performed about three years ago and that no trouble whatever has been experienced with the cylinders to date. Cylinder reclamation, in the case where the cylinders were not removed, can be accomplished for approximately 10% of the cost of new cylinders. However, it must be thoroughly understood that the nature of the fracture governs the reclamation cost. Cases may arise where the nature of the fracture is so serious as to result in a heavy reclamation expense. It must be understood that the determining factor as to whether or not the cylinders must be removed is the location of the fracture.

Guides

Another major operation consists in building up worn sides of guides. It is one of our shop practices to maintain the dimension of our guides standard. When removed from the engines the guides are first straight-

ened. They are then freed from all scale and foreign matter in order that they have a clean surface. In the building up process one operator preheats the guide, working just ahead of the second operator who applies the manganese bronze. Manganese bronze is used in this case because of its wear resisting properties which would not be the case if Tobin bronze is used. With the aid of this process we are able to build up a set of four guides in approximately two hours. Contrast this time interval, if you will, with the old practice of patch bolting strips of metal to the sides of guides which required approximately twenty hours to one set of four guides.

We also maintain our motion work parts standard, so far as lateral is concerned, by the application of Manganese Bronze to the wearing surfaces. In the past the worn end of the part fitting into the clevis was made sufficiently thick by blacksmith welding a piece on each side and machining so that the lateral motion in the clevis was thus taken up. We know that it is 60 to 75% more economical to build up both the clevis and the part fitting into it by gas welding and then machining both to standard dimensions.

Stoker Screws

Stoker screws wear rapidly when in use and often have to have the flights built up to standard dimensions in order that they can properly transfer the coal. Some time ago a brand of welding rod was furnished which may be applied either by gas welding or the electric arc. This welding rod when applied presents such a hard surface that it cannot be machined. We found that when this rod was applied with the electric arc our operators could not produce a smooth surface, which made it necessary to grind the outside edges of the flight. We then investigated the possibilities of applying the rod with the aid of the acetylene torch. It was found that our operators could produce a welded surface which required no grinding. While we do not know the length of life we may obtain we know that the service already obtained is such that the additional cost of applying the rod with the acetylene torch as compared with the electric arc is, at least, offset.

Just how much longer this conveyor screw will function remains to be seen but at the last shopping there were no appreciable signs of wear.

In this paper I have endeavored to explain in detail our shop procedure in handling the major items of repair common to our locomotive shop wherein the acetylene torch plays an important part. There are many other items which are reclaimed by the use of gas welding which are too numerous to mention.

Car Department

Thus far the paper has dealt only with work relating to the Locomotive Department. Gas welding is used to some extent in the Car Department though its use is far more restricted, due to the nature of the work.

When cracks are found in truck and body bolsters they are prepared for welding by chipping out the metal adjacent to the crack. The opening thus provided is acetylene welded, restoring the original contour of the material.

Another operation in the Car Department consists in building up worn knuckles. This operation results in a saving of approximately 84% as compared with replacing the worn knuckles with new ones.

Further use of gas welding is utilized in making repairs to damaged steel parts of rolling stock. Parts damaged beyond possibility of straightening are removed and replaced by welding sections or parts of sections in place.

Track

Track equipment such as battered rail ends and worn frogs is successfully reclaimed by this process. The worn portions characteristic to these parts, i.e., the points and adjacent wing rails are built back to original form, thereby prolonging their usefulness from 25 to 40%.

As this work is done in the field without it being necessary to remove the affected parts and without any delay to traffic a decided saving in labor is also realized.

While the gas torch plays a very important part in welding operations, an equally important part is its use in cutting operations. While certain material could be removed by hand or pneumatic tools there are countless illustrations where the cutting torch can be used many times more efficiently, due to the inaccessibility of the parts to be removed. Moreover, the cutting torch can be used efficiently in removing large size bolts. Of course, a rivet buster operated by two or three men could cut the large bolts off but we already know that one cutting operator with the acetylene torch can remove the bolts in question at a decided saving, at least 65%.

Another cutting operation is the economical use of the cutting torch in dismantling locomotives and cars. In addition to speeding up the dismantling process, the use of the acetylene torch permits the scrap to be cut to charging pot size. This feature results in securing better scrap value on the heavier parts that cannot be cut in the shears. Based on our past experience in dismantling locomotives, we know that a saving of 50% is effected by the use of the cutting torch as compared with the past practice of dismantling by the use of hand tools.

Furthermore, when sorting scrap the torch speeds up the work inasmuch as it aids in separating tangled scrap and large pieces that cannot be separated by hand.

Equally as important is the cutting of irregular-shaped scrap parts that cannot be entered in the shears.

Another place where the torch plays no minor part is its use in relief train service. With the aid of the torch we have found many cases whereby this equipment has expedited the clearing of a wreck to the extent of 25%.

In this paper I have endeavored to explain our procedure in handling the major items of repairs common to a railroad in which the gas welding plays an important part. There are countless other items that are either repaired or reclaimed that are too numerous to mention.

1931 BOUND VOLUME

Bound Volumes of the JOURNAL of the Society for the year 1931 are now available with imitation black leather covers. Contains a wealth of information on the latest developments in welding. Price $6.50.

Code for the Welded Construction of Low Pressure Tankage

Submitted by the Building Code Committee

Editor's Note: In October, 1928, the Executive Committee authorized the Committee on Building Codes to prepare a code covering low pressure tankage which might be used in building construction.

The Committee on Building Codes at its meeting in April, 1929, appointed a subcommittee composed of Messrs. J. L. Anderson, F. P. McKibben and James W. Owens, to outline the scope of the proposed code and this subcommittee prepared a tentative outline which is reproduced herewith as Exhibit A.

The Secretary of the main committee canvassed the principal city building departments and tankage manufacturers to develop what regulations are now in force, and whether a code is needed. This canvass disclosed the fact that the present building codes of very few cities contain regulations for the kind of tankage in question, whether welded or otherwise. It also disclosed diversity of opinion as to the need of a code.

The most specific provisions encountered were those of the Minneapolis building code of which pertinent excerpts are reproduced as Exhibit B. These statements are being published merely as information and not as recommendations of the committee.

The Committee on Building Codes concluded that there is not sufficient information available for the preparation of a code dealing with welded low pressure tankage.

The Editor of the JOURNAL, *in accordance with the recommendation of the Meetings and Papers Committee of the Society, invites those who have had experience in this field, or who are interested in its development, to submit papers on the subject with a view to their publication in the* JOURNAL *or presentation at a local or national meeting.*

EXHIBIT A

SCOPE OF CODE COVERING THE MANUFACTURE OF STATIONARY LOW PRESSURE WELDED TANKS FOR INSTALLATION IN BUILDINGS

1. General
   - (a) Substitution of welding for riveting
   - (b) Substitution of gas cutting for shearing
2. Scope
   - (a) Limits of pressure
   - (b) Limits of temperature
   - (c) Limitations of Code application
3. Definitions
   - (a) Forge welding
   - (b) Pressure welding
   - (c) Fusion welding
   - (d) Lap weld
   - (e) Butt weld
     - (I) Single vee
     - (II) Double vee
   - (f) Fillet weld
   - (g) Edge weld
   - (h) Corner weld
   - (i) Calk weld
   - (j) Tack weld
   - (k) Base metal
   - (l) Root of weld
   - (m) Throat of weld
   - (n) Weld length
   - (o) Weld dimensions
   - (p) Gas cutting
4. Materials
   - (a) Sheets—low carbon (tank steel—max. C = 0.20)
   - (b) Filler material
   - (c) Structural steel
5. Tank Types
   - (a) Closed
     - (I) Cylindrical
     - (II) Rectangular
     - (III) Odd shapes (oblong, oval, etc.)
   - (b) Open
     - (I) Cylindrical
     - (II) Rectangular
     - (III) Odd shapes (oblong, oval, etc.)
6. Tank Design
   - (a) Limits of capacity
   - (b) Ratio length to diameter
   - (c) Relation thickness of sheets to tank dimensions and service
   - (d) Stiffening rings
   - (e) Bracing (flat heads—rectangular sides)
   - (f) Cylindrical tank head dimensions
     - (I) Radius of dish
     - (II) Height of flange
   - (g) Staggering of longitudinal joints in different courses
   - (h) Limits to length of longitudinal seams
   - (i) Heating internally or externally
   - (j) Recognition of existing regulations
7. Welded Joint Design
   - (a) Butt
   - (b) Lap
   - (c) Combination rivet and weld or calk weld
   - (d) Edge weld
   - (e) Corner weld
   - (f) Circular head welds
     - (I) Simple flat heads
     - (II) Simple dished heads
     - (III) Flanged flat heads
       - (a) Height of flange
       - (b) Location of weld
       - (c) Size of weld
     - (IV) Flanged dished heads
       - (a) Height of flange
       - (b) Location of weld
       - (c) Size of weld
   - (g) Welding of pipe connections
   - (h) Welding of opening reinforcements
8. Erection and Installation
   - (a) Field erection
   - (b) Nature of support

(c) Thermal insulation
(d) In accordance with Code I, Part A
(e) Recognition of existing regulations

9. Workmanship
   (a) Shearing and preparation
   (b) Accuracy of rolling
   (c) Cleaning surface to be welded
   (d) Limiting deformation due to localized strains
   (e) Tacking
   (f) Use of clamps
   (g) Painting and galvanizing
   (h) Gas cutting in fabrication and repairs
   (i) Tolerances for head fit

10. Testing
   (a) Hydrostatic
   (b) Compressed air

Tank Specification Scope as to Class of Service and Type of Building Where Installed

Type of Building	Class of Service										
	Stand. Pipe Water Supply	Sprinkler Water Supply	Sanitary Water Supply	Fuel Oil	Refrig-erating Brine	Process Fluids	Acids	Oils	Gasoline	Gas	Lye
Hospital											
School											
Office Building											
Apartment House											
One-Family Dwelling											
Department Store											
Manufacturing Building											
Cleaning & Dyeing Est.											
Warehouse											

EXHIBIT B

EXCERPTS FROM AN ORDINANCE CITY OF MINNEAPOLIS FIRE DEPARTMENT FIRE PREVENTION BUREAU

Dated Dec. 27, 1929

Storage Must Be Outside Buildings

SECTION 44. Except as otherwise permitted in this ordinance, the storage of flammable liquids shall be outside buildings, in underground tanks or above ground tanks; except that the storage in tanks above ground or outside buildings is prohibited within the fire limits in the City of Minneapolis as the same may now or hereafter be defined by the ordinances of said City, and on land near streams or other waterways which would carry burning liquid into congested districts. Provided that for existing tanks within such limits, which are properly safeguarded, and do not involve a hazard to other property, a permit shall be granted.

Underground Storage Limited

SECTION 45. Tanks buried underground shall have the top of the tank not less than 4 feet below the surface of the ground, and below the level of any piping to which the tanks may be connected. Where necessary, to prevent floating, tanks shall be securely anchored or weighted.

The limit of storage permitted shall depend upon the location of tank with respect to the building to be supplied and adjacent buildings, as follows:

Maximum Capacity of Tanks for Underground Storage

Location	Class I, II and III. Under 100 Degrees F. Flashpoint.	Class III Above 100 Degrees F. Flashpoint.
If top of tank is lower than all floors, basements, cellars or pits of all buildings.		
A—Within a radius of 50 feet	Unlimited	Unlimited
B—Within a radius of 40 feet	50,000 Gallons	500,000 Gallons
C—Within a radius of 30 feet	20,000 Gallons	200,000 Gallons
D—Within a radius of 25 feet	15,000 Gallons	150,000 Gallons
E—Within a radius of 20 feet	5,000 Gallons	100,000 Gallons
F—Within a radius of 10 feet	2,000 Gallons	75,000 Gallons
G—If within 10 feet of any building, and the top of tank is above the lowest floor, basement, cellar or pit of the building.	500 Gallons	50,000 Gallons

H—Tanks containing Class I, II and III liquid, under 100 degrees F. Flashpoint located beneath a building, shall be below all portions of that building and limited in number and capacity to two 1000 gallon tanks or four 550 gallon tanks. Such tanks shall be located with respect to other buildings as given above under "F," and the top of said tanks shall be buried not less than 2 feet below the surface of the ground, except that, in lieu of the 2-foot cover, tanks may be buried under 12 inches of earth and a cover of reinforced concrete at least 6 inches in thickness provided, which shall extend at least one foot beyond the outline of tanks in all directions; concrete cover to be placed on a firm, well-tamped earth foundation.

I—A tolerance of 10 per cent in capacity shall be allowed in tanks of 150,000 gallons or less capacity.

Capacity and Location of Above-Ground Tanks

SECTION 46. In case of tanks for the storage of Class I, II and III liquids at marketing stations, wholesale storages, port terminals and other properties where flammable liquids are stored in quantities the distance from the line of adjoining property which may be built upon shall in no case be less than set forth in Table 1, nor less than double these distances in the case of tanks for the storage of crude petroleum. In particular installations these distances may be increased at the discretion of the authority having jurisdiction after con-

sideration of the special features such as topographical conditions; nature of occupancy and proximity to buildings on adjoining property and height and character of construction of such buildings; capacity and construction of proposed tanks and character of liquids to be stored; degree of private fire protection to be provided, and facilities of the Fire Department to cope with oil fires. Consideration of these features shall also determine the distances for tanks of capacities of over 50,000 gallons.

Table 1—Minimum Distance of Outside Above-Ground Tanks for Class I, II and III Liquids Other than Crude Petroleum to Line of Adjoining Property Which May Be Built Upon

Capacity of Tank, Gallons	Minimum Distance to Line of Adjoining Property Which May Be Built Upon
0 to 12,000	10 feet
12,001 to 24,000	15 feet
24,001 to 30,000	20 feet
30,001 to 50,000	25 feet

At marketing stations and elsewhere truck loading racks shall be separated from tanks, warehouses, and other plant buildings, by distances at least equivalent to those specified in Table 1.

The minimum distances between above-ground storage tanks shall be in accordance with the following table:

Table 2—Minimum Distances between Above-Ground Storage Tanks

(Applies to All Classes of Liquid)

Capacity of Tank (or of the larger of the two tanks between which distance is to be measured) Gallons	Minimum Distance between Tanks
300 or less	3 feet
500 or less	3 feet
1,000 or less	3 feet
8,000 or less	3 feet
12,000 or less	3 feet
18,000 or less	3 feet
24,000 or less	5 feet
30,000 or less	10 feet
48,000 or less	10 feet
75,000 or less	13 feet
100,000 or less	15 feet
150,000 or less	Distance equal to the diameter (or the greatest horizontal dimension if the tank is not cylindrical) of the tank, or of the larger of the two tanks between which distance is to be measured.
200,000 or less	
500,000 or less	
1,000,000 or less	
2,500,000 or less	

Openings in Above-Ground Tanks

SECTION 47. Each above-ground tank, inside or outside buildings, over 100 gallons in capacity shall have vent openings, excepting safety valves, provided with non-corrodible wire screens (preferably 40 x 40 mesh but not less than 30 x 30 or its equivalent) so attached as to completely cover the openings. Unless vent openings are adequate to relieve any excessive pressure, a safety valve shall be provided, or manhole covers shall be kept closed by weight only, and not firmly attached. The screens on openings may be made removable, but shall be kept normally firmly attached. The covers for manholes, handholes and gage holes shall be made tight fitting.

Material and Construction of Underground Tanks

SECTION 49. Tanks shall be constructed of galvanized steel, of open hearth steel or of wrought iron of a thickness not less than specified in Table 3. For liquids heavier than 35 degrees Baumé, tanks may be constructed of concrete in accordance with the Regulations of the National Fire Protection Association.

Table 3—Underground Storage Tanks

Capacity (Gallons)	Minimum Thickness of Material Gage U. S. Standard	Lbs. per Sq. Ft.
1 to 285	16	2.50
286 to 560	14	3.125
561 to 1,100	12	4.375
1,101 to 4,000	7	7.50
4,001 to 12,000	1/4 inch	10.00
12,001 to 20,000	5/16 inch	12.50
20,001 to 30,000	3/8 inch	15.00

For tanks of 1100 gallons and more, a tolerance of 10 per cent in capacity shall be allowed.

Tanks of open hearth steel or wrought iron thinner than No. 7 gage shall be galvanized.

For Class III liquids, if adequate internal bracing is provided, tanks from 12,001 to 30,000 gallons capacity may be built of steel plate 1/4 inch thick.

All joints of tanks shall be riveted and calked, brazed, welded, or made tight by some equally satisfactory process. Tanks shall be tight and sufficiently strong, to bear, without injury, the most severe strains to which they may be subjected in use. Shells of tanks shall be properly reinforced where connections are made, and all connections made through the top of the tank above the liquid level.

Tanks for systems under pressure shall be designed for four times the maximum working pressure, and tested to twice the maximum working pressure.

All iron or steel tanks shall be thoroughly coated on the outside with tar, asphaltum or other suitable rust-resisting material. Where soil contains corrosive substances, such special protection shall be provided as may be required by the Chief of the Fire Department.

With the approval of the Chief of the Fire Department, tanks of copper or other suitable material may be used if, after the necessary handling incident to installation, they are equivalent in strength, rigidity, durability and tightness to the steel or iron tanks described above.

Material and Construction of Above-Ground Tanks

SECTION 50. Tanks (including tops) shall be constructed throughout of open hearth steel or of wrought iron of a thickness in accordance with the following requirements. No open tank shall be used. For liquids of 35 degrees Baumé or heavier, tanks may be constructed

of concrete in accordance with the Regulations of the National Fire Protection Association.

(a) Horizontal or Vertical Tanks Not Over 1100 Gallons Capacity

Capacity (Gallons)	Minimum Thickness of Material
1 to 60	18 gage (U. S. Std.)
61 to 350	16 gage "
351 to 560	14 gage "
561 to 1100	12 gage "

(b) Horizontal Tanks Over 1100 Gallons Capacity

Tanks having a diameter of not over 6 feet shall be made of at least $^3/_{16}$ inch steel. Tanks having a diameter of over 6 feet and less than $11^1/_2$ feet shall be made of at least $^1/_4$ inch steel.

(c) Vertical Tanks Over 1100 Gallons Capacity

Tanks of this class shall be of such material and so constructed as to have a factor of safety of at least 2.5.

The minimum thickness of shell or bottom shall be $^3/_{16}$ inch. The minimum thickness of roof shall be $^1/_8$ inch.

The thickness of plates shall be in accordance with the following formula:

$$t = \frac{2.604 \times H \times D \times F \times S}{T \times E}$$

where t = thickness of plate in inches.
H = height of tanks in feet above the bottom of the ring under consideration.
D = diameter of the tank in feet.
F = factor of safety (taken as 2.5).
S = specific gravity of liquid stored (water = 1).
T = tensile strength of plate in pounds per sq. in.
E = efficiency of vertical joint in ring under consideration.

The tensile strength of the steel shall be taken as 55,000 pounds per square inch, and the shearing strength of rivets shall be taken as 40,000 pounds per square inch.

Tanks shall be riveted, welded or brazed and shall be calked or otherwise made tight in a workmanlike manner. The top of the tank shall be securely fastened to top ring with joints having the same tightness as the joints between the rings.

All iron or steel tanks shall be thoroughly coated on the outside with tar, asphaltum or other suitable rust-resisting materials.

Roofs or tops of tanks shall have no unprotected openings. Roofs or tops shall be firmly and permanently jointed to the tank and all joints shall be riveted and calked, brazed, welded, or made tight by other process satisfactory to the Chief of the Fire Department.

Except in oil refineries or large water terminals, tanks containing flammable liquids having flashpoint below 70 degrees F. (closed cup tester) shall have painted conspicuously upon the side the wording "FLAMMABLE—KEEP FIRE AWAY."

With the approval of the Chief of the Fire Department, tanks of copper or other suitable material may be used, if, after the necessary handling incident to installations, they are equivalent in strength, rigidity, durability and tightness to the steel or iron tanks described above. For liquids of 35 degrees Baumé or heavier, tanks may be constructed of concrete in accordance with the Regulations of the National Fire Protection Association.

Construction of Tanks

SECTION 51. Tanks shall be riveted, welded or brazed, and shall be soldered, calked or otherwise made tight in a mechanical, workmanlike manner, and if to be used with a pressure discharge system shall safely sustain a hydrostatic test at least double the pressure to which tank may be subjected. Top of tank shall be securely fastened to top ring, with joints of equal tightness to those between rings. Tanks shall be covered with asphaltum or other non-rusting paint or coating. All pipe connections shall be made through flanges or metal reinforcements securely riveted, welded or bolted to the tank and shall be made thoroughly tight.

Tanks shall be constructed entirely of metal, including top, sides and bottom; all openings shall be gas tight, except breather vent, which shall be screened as provided in Section 47.

Stationary Tanks in Buildings; Insulation of Tanks; Permissible Quantities

SECTION 53. Tanks in buildings shall be constructed and installed as follows:

(a) Tanks for Class II and III liquids of 120 gallons or less capacity shall be of galvanized steel or tin plate, suitable for the purpose, and with all joints locked, double seamed or riveted, and also soldered or made tight by some equally satisfactory method; material shall be of not less than No. 20 gage U. S. Standard, except that where used in connection with and in the same room with oil burning equipment, No. 16 gage metal shall be used. Original barrels or drums may be used until contents are drawn, if substantially placed to prevent tipping or rolling, with pump inserted through a close fitting connection in side or head.

(b) Tanks for Class II and III liquids of greater than 120 gallons capacity shall be of thickness specified in Table 2, Section 49, or of concrete, and shall be vented as specified in Section 55.

(c) Tanks shall be located below the level of any piping to which they may be connected, or if this is impracticable, arrangements satisfactory to the Chief of the Fire Department shall be made to prevent siphoning or gravity flow in case of accident to the equipment or piping.

(d) Tanks shall be set on a firm foundation and those exceeding 2500 gallons capacity shall be supported independently of the floor construction.

(e) Steel tanks exceeding 275 gallons capacity and installed in connection with oil burning equipments shall be completely enclosed with a heat insulation equivalent to reinforced concrete not less than 12 inches in thickness, with at least a 6-inch space on sides between tank and concrete insulation filled with sand or well-tamped earth, and with 12 inches of sand on top of tank, either between tank and concrete slab or above concrete slab.

(f) Concrete tanks shall be completely enclosed with a heat insulation of reinforced concrete not less than 8 inches in thickness, with at least a 6-inch space on sides between tank and concrete insulation filled with sand or well-tamped earth, except that for top of tank an insulation of 12 inches of sand without concrete covering shall be deemed sufficient.

(g) Walls of concrete tanks shall be constructed independently of and not in contact with the building walls.

(h) In ordinary buildings the gross capacity of tanks shall not exceed 5000 gallons.

(i) In fire-resistive buildings the gross capacity of tanks shall not exceed 10,000 gallons.

(j) In any building, if in a fire-resistive or detached room cut off vertically and horizontally in an approved manner from other floors of the main building, the gross capacity of tanks may be not exceeding 50,000 gallons, with an individual tank capacity not exceeding 25,000 gallons, providing the insulating sand specified under paragraphs (d), (e) and (f) shall be increased to 12 inches on sides and 18 inches on top.

Current Welding Literature

Aluminum Joints. Some Practical Notes on Jointing Aluminum, A. J. T. Eyles. Engineer (Dec. 11, 1931), Vol. 152, No. 3961, pp. 618–621.

Arc Welded Construction Helps Insure District Heating Service, E. R. Benedict. Heating and Ventilating (Jan., 1932), Vol. 29, No. 1, pp. 50–51.

Boiler Manufacture. Attitude of Eleven Utilities toward Welded Boilers. Mech. Eng. (Dec., 1931), Vol. 53, No. 12, p. 933.

Boiler Manufacture. Details of Boilerworks Practice, E. W. Thompson and A. Jeavons. Mech. World (Nov. 20, 1931), Vol. 90, No. 2342, pp. 498–499.

Charging Boxes and Buggies Built of Welded Plates. Steel (Jan. 11, 1932), Vol. 90, No. 2, p. 26.

Coal Mines and Mining. Electric Arc Welding in Mines, C. Lee. Elec. World (Nov. 28, 1931), Vol. 98, No. 22, pp. 953–954.

Coated Electrodes Make Welded Pressure Vessels Safe, G. Raymond. Welding (Dec., 1931), Vol. 2, No. 12, pp. 789–792.

Electric Welding. Control of Spot and Flash Welds, G. A. Hughes. Welding Engr. (July, 1931), Vol. 16, No. 7, pp. 33–36.

Electric Welding, Arc. History of Arc Welding as I Have Known It Personally, J. C. Lincoln. Master Boiler Makers' Assn.—Off. Proc., 1931, pp. 30–34.

Electric Welding, Arc. Quality and Its Relation to Cost in Welding, H. A. Rigby. Commonwealth Engr. (Nov. 2, 1931), Vol. 19, No. 4, pp. 144–146.

Electric Welding, Arc. The Metallic Arc, I, II and III, A. R. Moon. Commonwealth Eng. Vol. 19, Nos. 1, 2 and 3 (Aug. 1, 1931), pp. 21–26; (Sept.) pp. 58–62 and (Oct.), pp. 99–104.

Electric Welding, Resistance. Resistance Welding, L. B. Wilson. Mech. World (Oct. 30, 1931), Vol. 90, No. 2339, p. 433.

Gas Plants. Welded Gasworks Plant Construction, E. Marshall. Gas Engr. (Dec., 1931), vol. 48, no. 13, pp. 712–713.

Industrial Plants. Arc-Welded Factory Building in Canada. Engineer (Dec. 11, 1931), Vol. 152, No. 3961, pp. 617–618.

Jigs and Fixtures. Making Electrically Welded Jigs in Russia, W. Wells. Machy. (N. Y.), Vol. 38, No. 4 (Dec., 1931), pp. 248–249.

Lead Welding. Autogenous Welding of Lead and Its Alloys—Ancient and Modern, E. B. Partington. Welding Jl. (Oct., 1931), Vol. 28, No. 337, pp. 304–310.

Lead Welding. Autogenous Welding of Lead and Its Alloys—Ancient and Modern, E. B. Partington. Machy. Market (Nov. 20, 1931) Nos. 1620 and 1621, pp. 19–20 and (Nov. 27), p. 15.

Lead Welding. Autogenous Welding of Lead and Its Alloys—Ancient and Modern, E. B. Partington. Metal Industry (Lond.), Vol. 39, No. 21, (Nov. 20, 1931), pp. 487–489.

Locomotive Boilers. Welding Practice in Northern Pacific Boiler Shops, Boiler Maker (Nov., 1931), Vol. 31, No. 11, pp. 303–305. Instructions covering boiler patching methods employed by Northern Pacific.

New Procedure Speeds Arc Welding of Pipe Lines, E. W. P. Smith. Pipe Line News (Jan., 1932), Vol. 4, No. 2, pp. 19–20.

Nickel Welding. Correct Welding of Nickel and Its Alloys Employed in Chemical Equipment, F. G. Flocke. Chem. Markets (Dec., 1931), Vol. 29, No. 6, pp. 601–605.

Non-Ferrous Metals. The Oxy-Acetylene Welding of Copper and Aluminum and Some of Their Alloys, F. A. Westbrook. Metal Industry (N. Y.), Vol. 29, No. 11, (Nov., 1931), pp. 469–470.

Office Buildings Welded. Arc Welding Solves Some Problems at DuPont Company's Fourteen-Story Office Building in Wilmington, Del., F. P. McKibben. Gen. Elec. Rev. (Dec., 1931), Vol. 34, No. 12, pp. 725–728.

Oxy-acetylene Cutting. Some Methods and Effects of Machine Gas Cutting, L. M. Curtiss. Iron Age (Nov. 19, 1931), Vol. 128, No. 21, pp. 1305–1307.

Oxy-Acetylene Welding. Development of Oxy-Acetylene Fusion Welding Process, F. C. Hasse. Boiler Maker (Nov., 1931), Vol. 31, No. 11, pp. 295–298.

The Oxy-Acetylene Welding of Copper Fire-Boxes of Locomotives, L. Saccomani and R. Verzillo. The Welding Journal (Dec., 1931), Vol. 28, No. 339, pp. 371–373.

Petroleum Refineries. Welding and Testing New Cracking Unit, E. Ellsberg. Iron Age (Nov. 26, 1931), Vol. 128, No. 22, pp. 1362–1365 and 1412.

Pipe Welding. The Welding of Copper and Brass Pipe, H. V. Inskeep. Eng. Soc. Boston—Jl. (Dec., 1931), Vol. 2, No. 10, pp. 17–24.

Present Use of Welding in the Pressure Vessel Field, W. Spraragen. The Iron Age (Jan. 14, 1932), Vol. 129, No. 2, pp. 161–165.

Pressure Vessels. New Code for Fusion Welding Likely to Be Misapplied, F. G. Sherbondy. Steel (Nov. 30, 1931), Vol. 89, No. 23, pp. 35–36.

Railroad Maintenance of Way. Maintenance Welding, E. L. Quinn. Ry. Jl. (Nov., 1931), Vol. 37, No. 11, pp. 20–22.

Railroad Signals and Signaling. Signal Bonds Installed by Electric Carbon Arc Welding on Canadian Pacific Railway. Can. Ry. and Mar. World (Nov., 1931), No. 405, p. 685.

Resistance Welding Budd Bodies, D. J. Rahn. Welding (Dec., 1931), Vol. 2, No. 12, pp. 802–803 and 807.

Shipbuilding. Arc Welding in Shipbuilding, H. W. Pierce. Soc. Naval Architects and Mar. Engrs. Advance Paper No. 14, for mtg. Nov. 19–20, 11 pp.

Stainless Steel. Welding of Stainless and Corrosion Resistant Alloys, W. B. Miller. Metal Progress (Dec., 1931), Vol. 20, No. 6, pp. 68–72. Practice of welding high- and low-carbon stainless steels, ferritic chromium-iron, chromium-nickel-iron, high chrome-nickel alloys and heat-resistant alloys.

Structural Steel. Metallic Arc, A. R. Moon. Commonwealth Engr., Vol. 19, Nos. 1, 2 and 3 (Aug. 1, 1931), pp. 21–26; (Sept. 1), pp. 58–62; (Oct. 1), pp. 99–104. Analytical discussion of metallic arc and procedure control of welding structural mild steel with flux-covered electrodes; influence of plate thickness on impact strength; comparison of properties of weld metal and mild steel.

The Welding Contractor in Steel Construction, G. D. Fish. Welding (Dec., 1931), Vol. 2, No. 12, pp. 799–801.

Water Pipe Lines. Arc Welded Pipeline for Hydraulic Mining, R. F. Allen. Min. Mag. (Dec., 1931), Vol. 45, No. 6, pp. 329–337.

Weld Strength Demonstrated. The Welding Engineer (Dec., 1931), Vol. 16, No. 12, pp. 25–26.

Welded Hip and Valley Roof, F. W. Jacoby. The Welding Engineer (Dec., 1931), Vol. 16, No. 12, pp. 39–42.

Welded Piping Produced for Wide Application. Steel (Jan. 18, 1932), Vol. 90, No. 3, p. 35.

Welded Steel Plates House Generators for Railroad Electrification. The Iron Age (Jan. 14, 1932), Vol. 129, No. 2, pp. 165–166.

Welded Structures, Castings and Forgings Compared. The Iron Age (Dec. 24, 1931), Vol. 128, No. 26, pp. 1620–1621.

Welding Machines. An Alternating-Current Arc Welder, J. B. Gibbs. Elec Jl. (Dec., 1931), Vol. 28, No. 12, pp. 665–667.

Welds. Strength of Arc-Welded Joints, F. R. Freeman. Instn. Civil Engrs.—Min. Proc., Vol. 231, pt. 1, 1930–31, pp. 283–304, and (discussion) 305–366, partly on supp. plate 5.

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